

Observations on the Insect Parasites of Some Coccidæ.

By

A. D. Imms, M.A., D.Sc.,

Reader in Agricultural Entomology in the Victoria University
of Manchester.

II. On Chalcid Parasites of *Lecanium capreæ*.

With 35 Text-figures.

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I. INTRODUCTION.

In the first paper of this series (Imms, 1916) a tolerably full account was given of the life-history of *Aphelinus mytilaspidis*, Le Baron, the chief parasite of the Mussel Scale (*Lepidosaphes ulmi*). The present contribution deals with certain features in the structure and life-economy of two abundant Chalcid parasites of *Lecanium capreæ*. Although the genus *Lecanium* comprises certain highly destructive insects, the species under consideration is not often of direct economic significance. An investigation of its insect enemies, however, has been prompted by the following considerations. Firstly, *Lecanium capreæ* is one of the most heavily parasitised of our indigenous Coccidæ, and a plentiful supply of material is readily available. Secondly, the parasitism is effectual to an exceptional degree in checking any undue abundance of the host. Thirdly, a study of the problems associated therewith, appeared to afford an exceptionally favourable opportunity for investigating the factors which contribute towards determining the efficiency of Hymenopterous parasites, as natural controlling agents. This research has been carried out in the Department of Agricultural Entomology, Manchester University, and at various localities in the field. I am again indebted to Prof. S. J. Hickson, F.R.S., for affording various facilities for prosecuting these investigations. Mr. A. A. Girault, of the U.S. Bureau of Entomology, has kindly examined the parasites in

question and identified them as *Aphycus melanostomatus*, Timberlake, and *Blastothrix brittanica*, Girault, sp. nov. Mr. J. T. Wadsworth, my research assistant, has rendered help in collecting material of the *Lecanium* from various localities, and in cutting serial sections for histological purposes.

II. OBSERVATIONS ON THE BIOLOGY OF THE HOST.

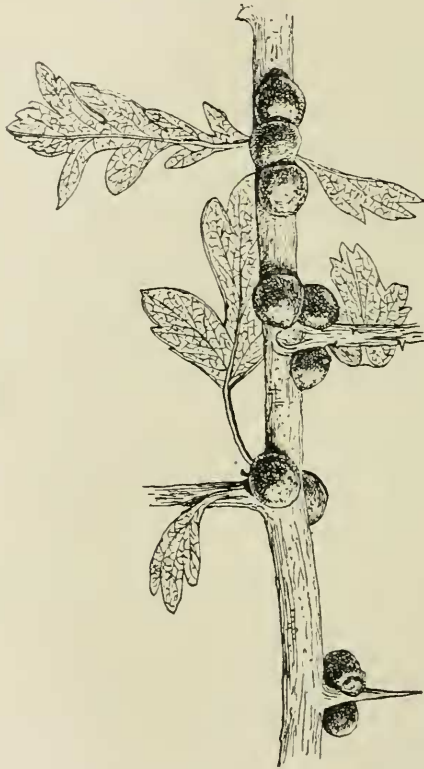
According to Newstead (1903, p. 112), *Lecanium capreae* is abundantly and generally distributed in suitable localities throughout England, but appears to be local in Scotland and Wales. I have met with it less plentifully in the southern counties of England than in the north midlands. It is common on the Continent of Europe (Marchal, 1908, p. 302), and also occurs in North America. Its principal food-plant is the hawthorn (*Cratægus oxycantha*), but I have also found it on lime (*Tilia europea*) and hazel (*Corylus avellana*). A few examples were also obtained from Horse Chestnut (*Æsculus hippocastanum*), sweet gale (*Myrica galea*), and apple (*Pyrus malus*). In addition to these host-plants others are recorded by Newstead (*loc. cit.*) and Marchal (*loc. cit.*).

Unless stated to the contrary, all observations mentioned in this paper were made upon material obtained from hawthorn.

From numerous observations, conducted in Cheshire, Lancashire, and Derbyshire during 1914-16, it was found that the young *Lecanium* larvæ commence to emerge from the eggs during the end of June. In 1914, from material obtained from Northenden (Cheshire), the larvæ commenced to appear in a field insectary on June 26th; they were very abundant on June 30th, and continued emerging until the middle of July. During 1915, ova obtained from the same locality commenced to hatch in a cool laboratory on June 17th. Shortly after emergence from the egg, the larvæ crawl freely over the twigs of the host-plant. They eventually reach the

leaves and take up positions near one of the principal veins on the under surface. The proboscis is inserted into the tissues, and the insect subsists upon the juices which it extracts therefrom. Shortly before the annual leaf-fall, the

TEXT-FIG. A.



A young twig of hawthorn (*Crataegus oxyacantha*) bearing ten fully-grown examples of *Lecanium capreae*; slightly larger than natural size.

larvæ migrate from the leaves on to the twigs. In Cheshire, this migration was found in 1915 to be most active during the second and third weeks in October. In 1916 the autumn was markedly warmer and the migration commenced during the fourth week in October. Upon reaching the twigs, the larvæ

usually establish themselves in or near the axils of the buds or bases of the thorns. On young and succulent twigs they are sometimes found scattered along the general surface of the shoot. Old and resistant shoots and branches are seldom utilised, and the positions which the larvæ take up during the autumn remain permanent, no further migration taking place. In almost all cases the ventral aspect of a twig is chosen. Where the branches or twigs are more or less vertically directed, no particular aspect appears to be selected. During the winter very little growth in size takes place, and unparasitised larvæ, measured on December 21st, 1915, averaged 1.1 to 1.3 mm. long and .7 mm. broad. On April 14th of the following year, larvæ from the same locality measured 2.1 to 2.5 mm. in length, and about 1.2 mm. in greatest breadth. After fertilisation, the females grow much more rapidly, and this goes on until the insect assumes the rounded, berry-like form shown in Fig. A. When fully grown, towards the end of May, the adult female scale insects measure from 5 to over 6 mm. along the antero-posterior axis, and approximately 3.75 mm. in transverse diameter. In the vertical plane they vary from 3 to about 5 mm. Considerably smaller examples, however, are not infrequently met with. The male covering scales are much smaller, elongate and flattened in form, and measure approximately 2.5 mm. in length. The winged males were observed to first appear during 1915 on May 5th, and in 1917 on May 15th. Females preponderate very greatly in number over the males, and were found at Knutsford (Cheshire) in the proportion of 86:9. In two localities near Northenden (also in Cheshire) the proportions were 77:4 and 5:1 respectively. Oviposition takes place at the end of May, or the first week in June, according to the prevailing climatic conditions. The number of eggs laid varies considerably and is to some extent proportional to the size of the parent insect. Counts were made on five average-size examples and the number varied from 1372 to 1919. According to Newstead (1903, p. 111) the number laid by a healthy female averages about 2000.

Tullgren (1906, p. 90) gives a similar estimate. After oviposition is fulfilled, the female rapidly declines and dies. Her shrivelled remains, invested by the scaly covering, function as a kind of brood-pouch, protecting the eggs until they hatch. Empty scales of the previous year are not infrequently found still adhering to the host-plant.

III. PARASITES PREVIOUSLY RECORDED FROM *LECANIUM CAPREÆ*.

Various Chalcid parasites have been recorded from *Lecanium capreæ* (Morley, 1910, p. 30), though none of them have been met with during the present investigations, and the majority appear to be infrequent in this country. With the exception of *Eunotus*, which belongs to the Pteromalidæ, all are members of the Encyrtidæ. In the accompanying list it will be observed that the host has been recorded under various specific designations, all of which, however, are now regarded as being synonyms of one and the same insect.

Parasite.	Authority.	Name under which host is recorded.
<i>Eunotus cretaceus</i> , Walk.	De Gaulle (1908, p. 103)	<i>Lecanium capreæ</i> , Linn.
<i>Eucomys obscura</i> , Dalm.	De Gaulle (1908, p. 98)	Coccid on <i>Tilia</i> .
<i>E. scutellata</i> , Swed.	Kawall (1855, p. 231)	<i>L. tiliaë</i> , Linn.
<i>Aphyeus punctipes</i> , Dalm.	De Gaulle (1908, p. 99)	<i>L. alni</i> , Modeer.
" "	Ratzeburg (1848, p. 146)	<i>L. alni</i> , Modeer.
<i>Blastothrix sericea</i> , Dalm.	Ashmead (1900, p. 390)	<i>L. æsculi</i> , Kol. <i>L. tiliaë</i> , Linn.
" "	Newstead (1903, p. iii)	<i>L. capreæ</i> , Linn.
<i>B. schonherri</i> , Westw.	Mayr (1875, p. 700)	<i>L. æsculi</i> , Kol.
<i>Microterys chalcostomus</i> , Dalm.	Mayr (1875, p. 719)	<i>L. æsculi</i> , Kol.
<i>M. sylvius</i> , Dalm.	Mayr (1875, p. 719)	<i>L. æsculi</i> , Kol.

IV. OBSERVATIONS ON *BLASTOTHRIX BRITANNICA*, GIR.

(a) Systematic Position.

The genus *Blastothrix*, like *Aphycus*, belongs to the sub-family Encyrtinæ of the Encyrtidæ.¹ It was likewise described by Mayr in the same memoir (1875, p. 697), in which he erected the latter genus. The various species may be readily distinguished by the fact that they are metallic or sub-metallic in appearance. In the females the joints of the funicle of the antennæ are longer than thick, and the marginal vein is present. According to Howard (1881, p. 365), the males are characterised by having the scape of the antenna less compressed than in the female; the pedicel is scarcely longer than thick, and is much shorter than the following joint; the joints between the pedicel and the club are strongly incised above at the articulations, and each joint bears upon its upper side two whorls of long erect hair.

Schmiedeknecht (1909, p. 241) catalogues nine species of *Blastothrix*, although eleven are quoted by Dalla Torre (1898, pp. 252-253). By the former authority *Blastothrix longipennis*, How., is regarded as a synonym of *B. sericea* (Dalm.); and, furthermore, he transfers *B. rosæ*, Ashm. to the genus *Aphidencyrtus*, Ashm.

(b) Habits and Distribution of the Genus *Blastothrix*.

Members of this genus are internal parasites during the larval stage, and attack Coccidæ of the genus *Lecanium*, living on various plant hosts, and also *Pulvinaria*. Two species, however, are apparently exceptions to this rule, i. e. *B. bifasciata*, which is recorded by Mayr (1875, p. 701), as follows: "Aus einer Zucht von Gallen der *Cynips cerri-cola*² erhielt ich im Mai zwei Weibchen, welche wahrscheinlich

¹ For the characters of the Encyrtidæ see p. 341.

² Hymenoptera fam. Cynipidæ.

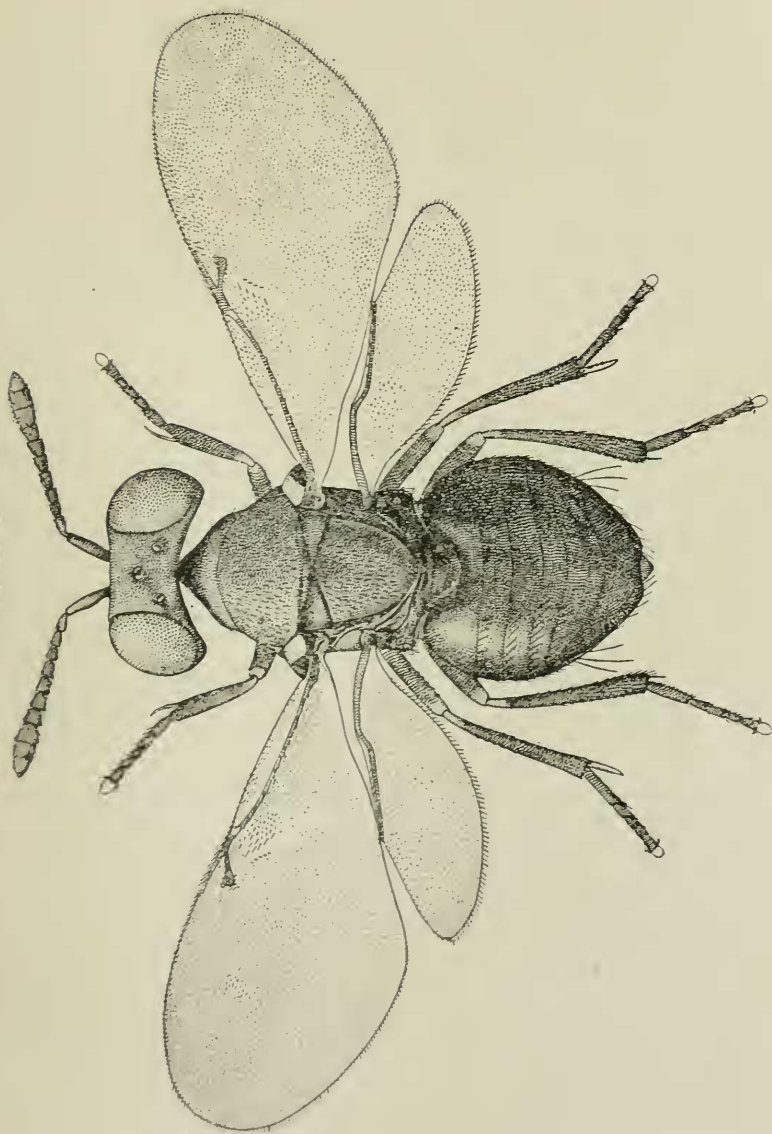
in Schildlausen auf Zerreichen lebten"; and *B. bohemani*, Westw., concerning which Mayr remarks (p. 700): "Diese Art lebt wahrscheinlich von Schildlausen an *Rubus cæsius* da ich aus siner grosseren Zucht von Gallen der *Lasioptera rubi*¹ im Mai des v J. II Exemplare erhalten habe und es nicht wahrscheinlich ist, dass sie aus den Gallen selbst gekommen seien."

The only published observations, known to me, dealing with the biology of any member of this genus are those of Newstead (1891, p. 31; 1893, pp. 66-67, 108-111, and 251), which relate to *B. sericea*. This author describes the effect which the parasite has upon the general form of its Coccid host, together with observations as to its method of oviposition and the larval feeding habits.

The genus *Blastothrix* is widely distributed in Central and Western Europe, and occurs also in North America, from Florida and the West Indies across to California. Of the European forms, two species are catalogued by Morley (1910, p. 22) as being British, viz. *B. bohemani*, Westw. and *B. sericea*, Dalm. The former is recorded by Walker (1838, p. 111) as being found on grass beneath trees near London, and the same writer (p. 106) records *B. sericea* from lime and oak trees near London. He also mentions North Wales, Ireland, and Scotland, while Newstead (1901, p. 1) states that it is the most widely distributed and the commonest of the British Coccid parasites. To these I am now able to add *B. britannica*, a species shortly to be described by Mr. A. A. Girault, from material which I sent originally to the United States National Museum for identification. *B. sericea*, Dalm is the only species listed by de Gaulle (1908, p. 99) from France, and its range also extends into Sweden, Germany, Austria, and North America. *B. bifasciata* Mayr occurs in Germany and Austria, *B. erythrostethus* (Walk.), in Austria, and *B. schonherri* (Westw.), in Germany. The remaining species catalogued by Schmiedeknecht are recorded from North America. *B. britannica* is an abundant species,

¹ Diptera fam. Cecidomyidæ.

TEXT-FIG. 1.



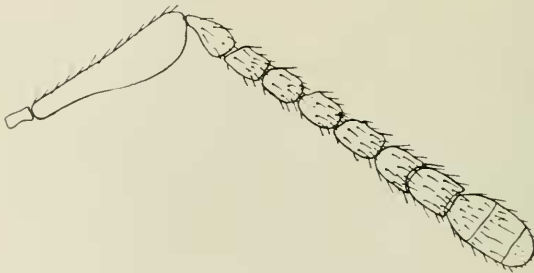
Blastothrix britannica, Gir, female. × circa 44.

and it is remarkable that it should have remained undiscovered for so long. It has been found plentifully in the following localities during the years 1914–17. Lancashire: West Didsbury near Manchester, and Fallowfield. Cheshire: Northenden, Knutsford, and Lymm. Derbyshire: Edale, Whaley Bridge, Marple, and Lathkil Dale.

(c) The Female.

Coloration.—Dark metallic, blue-green, inclining in many specimens to blue-black ventrally; the hairs investing

TEXT-FIG. 2.



Blastothrix britannica, Gir., female. Left antenna, viewed laterally.

the head and trunk white. The eyes are pruinose, and the ocelli vary from deep crimson to almost black. The scape of the antenna is brown-black with metallic reflections; the remaining joints are smoky brown, those forming the pedicel and club being the darkest; frequently the last joint of the funiculus is paler than the preceding joints. The tegulae are dirty white basally and dark brown distally. The legs are dark, smoky brown; the distal ends of the femora and the proximal and distal ends of the tibiae of the fore and middle legs, the distal ends of the femora, and the proximal ends of the tibiae of the hind legs, and the tibial spurs and first tarsal joints of the middle legs are dirty white.

The Head.—The head is as broad as the maximum width of the thorax, and is much compressed in the antero-posterior plane; when viewed from its anterior aspect it is shaped like an equilateral triangle with the angles greatly rounded. The eyes are distinctly hairy, and the ocelli are disposed in such a manner that the posterior pair are situated individually nearer to the eyes, and to the hind margin of the head, than to the median unpaired ocellus (Fig. 1). The antennæ (Fig. 2) measure 1 mm. long, and are 2-jointed, the joints being mutually related in length in the following proportions:

TEXT-FIG. 3.

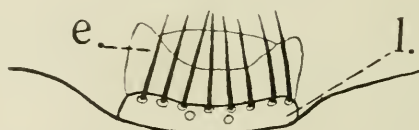
Blastothrix britannica. Gir. female. Right mandible. $\times 325$.

Basal joint.	Scape.	Pedicel.	Funiculus.	Club.
3	19	6	4 : 4 : 5 : 5 : 4 (2-3) (3-4) (6-7) (6-7)	5 : 4 : 4 (10-12) (12-13) (7-8)

On the 5th. to 11th joints elongate rod-like sensoria are evident, and their average numbers are indicated above in brackets, placed beneath the respective joints. The mandibles (Fig. 3) are closely similar to each other, somewhat quadrangular in form, with the points of muscular insertion and the articular surfaces but little emphasised. Each mandible measures $.17 \times .1$ mm., it is bluntly and

unequally bi-dentate, and about 14-16 slender bristles are present on its upper surface. Situated dorsally to the mandibles is a stout transverse chitinised bar, as is frequent among Chalcids; one of its functions appears to be that of affording support to the anterior margin of the mouth. The labrum (labrum superioire of some authorities) is extremely short, and extends between the bases of the mandibles; it measures $\cdot 008$ mm. long, and has a breadth of $\cdot 07$ mm.; its anterior edge is slightly concave, and is armed with 7-8 stout marginal setæ (Fig. 4). The epipharynx (*e.*) is a broad membranous lip-like structure projecting from beneath the labrum; its surface is clothed with minute hairs, and its antero-dorsal margin is deeply incised to form a well-marked sinus.

TEXT-FIG. 4.

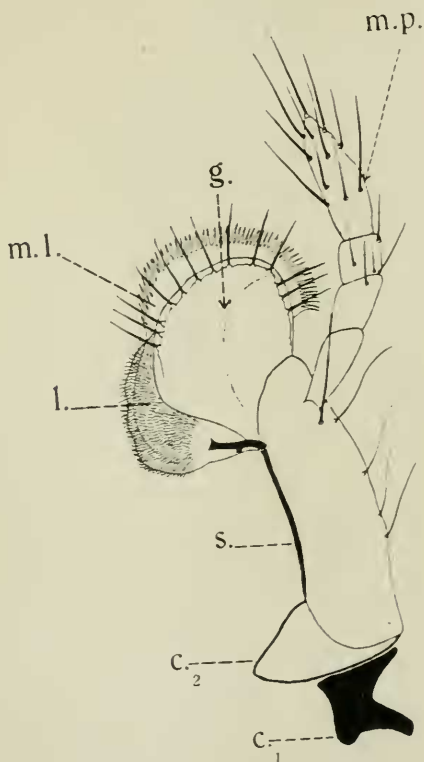


Blastothrix britannica, Gir., female. Labrum seen from above.
l. labrum. *e.* Epipharynx. $\times 250$.

The first maxillæ (Fig. 5) are somewhat complex in structure, and each measures $\cdot 30$ mm. in length. The cardo appears to be represented morphologically by two separate elements—a proximal and a distal. The proximal sclerite (*c.*₁) is densely chitinised, almost black in colour, and somewhat boot-like in form, with the toe of the boot directed outwards. The distal sclerite (*c.*₂) is triangular, with its apex directed inwards and in contact with that of its fellow of the opposite side. What may be regarded as the base of the triangle articulates with the stipes, and does not exhibit any special chitinisation; the two sides, on the other hand, are markedly thickened. The stipes (*s.*) is the largest element in the maxilla, and attains a length of $\cdot 17$ mm., with an average breadth of $\cdot 05$ mm. Its inner side is strengthened by a chitinous rod, which articulates at its distal extremity

with the postero-lateral angle of the mentum; its proximal extremity is in contact with the cardo (c_2). The maxillary palpi are well developed and measure .17 mm. long; each palp is four-jointed, with the joints related to one another in

TEXT-FIG. 5.

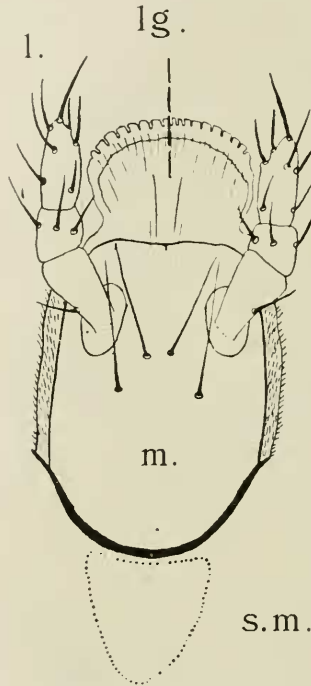


Blastothrix britannica, Gir., female. First maxilla seen dorsally. c_1 , c_2 . Cardio. g . Galea. l . Lacinia. $m.l.$ Membranous lobe of lacinia. $m.p.$ Maxillary palp. s . Stipes. $\times 250$.

the approximate ratio of 3:2:2:5. At its apical extremity the stipes carries two much-flattened lamellate lobes, which, however, are closely adpressed and incompletely separated from each other. The outer and ventral lobe is the stouter of the two, and very possibly is to be regarded as being the

galea (*g.*); its free margin and outer surface are provided with stout elongate setæ. The inner lobe or lacinia (*l.*) is membranous and finely hairy. Attached thereto is an extremely thin and transparent membrane with a deeply

TEXT-FIG. 6.



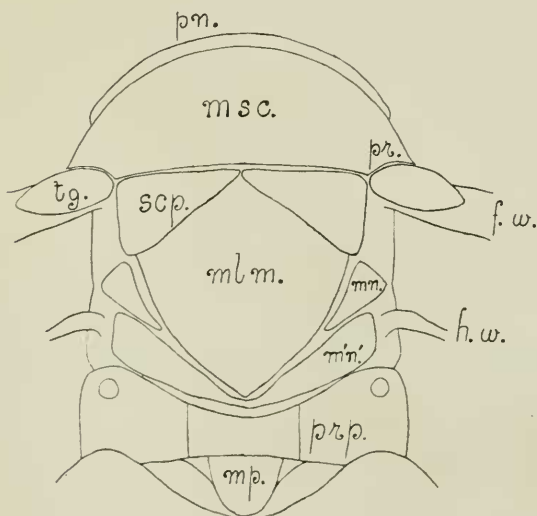
Blastothrix britannica, Gir., female. Labium (second maxillæ) seen ventrally. *l.* Labial palp (right). *lg.* Ligula. *m.* Mentum. *s.m.* Sub-mentum. $\times 270$.

pectinate margin (*m.l.*); on account of its remarkable delicacy and transparency this structure is liable to be overlooked.

The labium (second maxillæ) is embraced, as it were, by the first maxillæ and very largely maintained in position by means of its attachments to the latter. The median unpaired portion of the labium (Fig. 6) measures .16 mm. long

and .076 mm. in maximum breadth; it is divisible into a semi-transparent distal element or ligula (*lg.*), and a more firmly chitinised basal element or mentum (*m.*). The posterior border of the mentum is strengthened by means of an edge or band of dark chitin; the extremities of this band articulate with the chitinous inner margin of the first maxilla of either side. On the pharyngeal aspect, its sides are

TEXT-FIG. 7.



Blastothrix britannica, Gir., female. Thorax viewed from above (diagrammatic). *f.w.* Base of fore wing. *h.w.* Base of hind wing. *mlm.* Mesoscutellum. *mn.*, *m'n'*. Metanotum. *mp.* Mesophragma. *msc.* Mesoscutum. *pn.* Pronotum. *pr.* Parapsides. *prp.* Propodeum. *tg.* Tegula.

supported by firm pads densely clothed with fine hairs. Situated behind the posterior border of the mentum is a small triangular membranous area, which is probably to be interpreted as being a vestigial sub-mentum (*s.m.*). The base of the ligula is slightly overlapped on its ventral aspect by the anterior margin of the mentum. The free distal edge of the ligula is crenated, and its inner or pharyngeal surface is markedly convex and beset with 6-8 regularly arranged rows

of chitinous papillæ. Within the mouth-cavity, and situated at the base of the ligula on either side, is a chitinous pad or sclerite bearing a large number of slender bristles; this structure appears to subserve some function in relation with swallowing the food. The labial palpi (*l.*) measure .087 mm. in length, and are three-jointed, the joints being related to one another in the proportion of 7:3:5.

The Thorax (Fig. 7).—In dealing with the thorax I have adhered to the same nomenclature of the parts as was used in my previous paper in this series (Imms, 1916, p. 227). The whole of the surface of the cuticle of the mesothorax bears a uniform, finely reticulated pattern; on the tegulæ the cellular pattern assumes a more elongate form than elsewhere.

The pronotum (*pn.* in Fig. 7) is of the usual narrow, band-like character; both it and the mesonotum are invested dorsally with numerous short, uniform, adpressed hairs. The mesoscutum (*m.sc.*) and its parapsides (*pr.*) form an extensive continuous area, sutures separating the former from the latter being wanting. The tegulæ (*tg.*) are very large and conspicuous. The mesoscutellum (*mlm.*) is extensive, longer than the mesoscutum, and separated from the latter by the well-developed scapulæ (*scp.*). The mesophragma (*mp.*) is less developed than in *Aphelinus*, but is clearly visible dorsally as a mammiliform tubercle fitting into the deeply formed sinus of the first segment of the abdomen. The metanotum is represented by the triangular sclerites (*mn.*), one on either side of the mesoscutellum, and by a narrow, band-like portion, unpaired and crescentic in form (*m'n'*). The propodeum (*pp.*) is likewise band-like in character, constricted in the median line, but notably expanded on either side; it bears the usual pair of large circular spiracles.

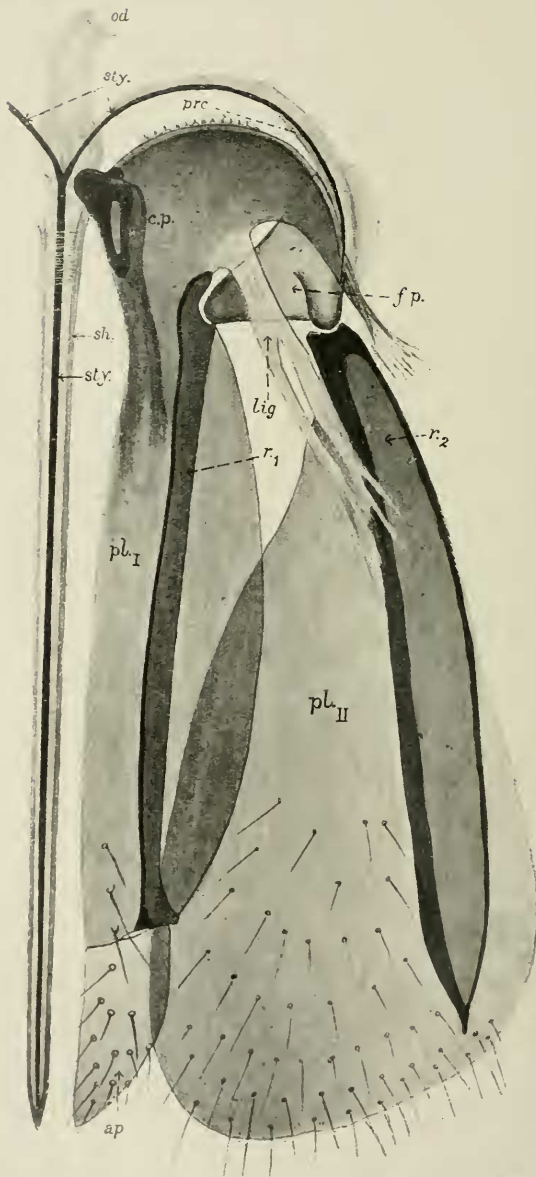
The fore-wings (Fig. 1) are finely pilose except for a small hairless tract extending obliquely backwards from a point near the stigmal vein. This area is clearly the homologue of the well-defined hairless belt, which is a

characteristic feature of the wings of *Aphelinus*. In the present species it is imperfect and does not, as a rule, extend to the posterior margin of the wing. In this respect, however, it is somewhat variable, certain individuals having the hairless tract extending right across the wing, while in others the area is more limited in extent. At its point of origin, near the root of the stigmal vein, the proximal edge of the clear tract is demarcated by 4-6 setæ rather larger and more conspicuous than those found elsewhere on the wing membranes; opposite these, on the distal margin of the same area, is a row of six peg-like processes. The sub-marginal, marginal, post-marginal, and stigmal (or radial) veins are related to one another in length in the proportion of 38:4:8:7. A well-marked clear area or "break" is present at the junction of the sub-marginal and marginal veins. The stigmal vein is slightly bifurcate at its apex and bears four rounded annuli or "cells"; these latter objects are frequent among Chalcids, and are possibly sensory organs fulfilling some obscure function. Marginal hairs commence at a point close to the base of the wing and extend around the latter until they reach the chitinous edge or rim on the hind margin, where they appear.

In the hind-wings, the single vein is confluent with the anterior margin for the first half of its course after which it becomes sub-marginal in position; its apex is somewhat expanded and bears three hook-like setæ which fit into the chitinous rim (already referred to on the fore-wing), thereby retaining the two wings together when the insect is in flight.

In the three pairs of legs the ratio of the length to the maximum breadth of the femora is as follows: 4:1, 6:1, 4:1; and of the tibiæ, 4:1, 25:3, 8:1. The tarsal joints measured along the dorsal edge (excluding the onychia and claws) are related to one another in length in the proportion of 12:8:7:7:12, 24:11:7:7:13, 19:11:9:7:14. The tibial comb of the fore-legs is composed of six slender bristles; the apical spur is long and slender, measuring

TEXT-FIG. 8.



Ovipositor and sheath of *B. britannica*, together with their associated parts of the left side, seen from the ventral (external)

·13 mm. long, unequally bifid, hairy on its ventral aspect and curved inwards. In the middle legs the tibial comb consists of six or seven short, thick, peg-like teeth; the spur measures ·13 mm. long and ·02 mm. in thickness across the middle region, and is closely invested with fine hairs. Short teeth, similar to those of the tibial comb, are present on the plantar surface of the first four tarsal joints. The tibial comb of the third pair of legs consists of about twenty slender bristles and the spur measures ·07 to ·09 mm. in length.

The Abdomen.—The abdomen is broad and slightly flattened, and consists of seven visible tergites (Fig. 1). The anterior margin of the first tergite (morphologically the second tergite) is very deeply incised, forming a prominent sinus receiving the mesophragma; the form and disposition of the remaining tergites are shown sufficiently clearly in Text-fig. 1 to render further description unnecessary. On the ventral aspect five sternities are evident, and what appears to be a divided sixth sternite is represented by a pair of plates on either side of the outer plates of the ovipositor. These plates are the "Ecailles chitineuses" of Bugnion (1890, p. 514 and Pl. 25, fig. 52), and are apparently wanting in *Aphelinus* (Imms, p. 231).

The ovipositor (Fig. 8), in the retracted condition, does not project beyond the apex of the abdomen. It is composed of the same chitinous parts which occur in *Aphelinus*, but, owing to their greater size and stouter nature, they are more easily studied than in the latter genus. The stylets (*sty.*) measure ·40 mm. in length, and each has an average diameter of ·007 mm., becoming narrower and obliquely pointed at its apex. The sheath (*sh.*) is as nearly as possible of the same length as the stylets which it protects.

surface. The stylets have been separated anteriorly from the corresponding portions of the sheath. *ap.* Palp-like appendage of inner plate. *f.p.* Fuleral plate. *lig.* Ligament. *od.* Common oviduct. *pl₁*, *pl₂*. Inner and outer plates. *prc.* Splint-like process of fuleral plate. *r₁* and *r₂*. Median ribs of outer and inner plates. *sh.* Sheath of ovipositor. *sty.* Stylets. × 360.

It consists of a pair of elongate pieces completely fused together to form a median groove. The edges of the groove are thicker than the remainder of the sheath and appear as a pair of sharply defined refractive lines. Basally, the paired nature of the sheath becomes evident, as its component parts are no longer fused, but take the form of a pair of diverging arms which curve upwards in a manner similar to the corresponding parts of the stylets. At its apex the sheath is pointed, and armed with three minute teeth on each side. The sheath and its curved arms function as guides to the stylets of the ovipositor, which are closely associated with them. On either side of the sheath are two conspicuous lamellæ—the outer and inner plates. The inner plates (*pl.*₁) are elongate structures, .43 mm. in length with an average breadth of about .04 mm. Anteriorly, each inner plate expands in the vertical plane, and has a crescentic margin of such a shape that it closely fits into a groove in the arm of the ovipositor sheath. Unless carefully disarticulated after maceration in weak potash, the arm of the ovipositor sheath is so closely attached to the margin of the inner plate that it appears as if it were merely the thickened rim of the latter (vide Fig. 8). At its apex, each plate bears a moveably articulated palp-like appendage (*ap.*) possibly tactile in its function. Towards its base the inner plate presents a powerful chitinised process (*c.p.*), which is closely related to its counterpart of the opposite side, though not in actual contact with it. The main function of this process seems to be to help to maintain the sheath of the ovipositor in position. Passing down the inner plate is a prominent median rib (*r.*₁) of chitin; this structure imparts rigidity, and, at the same time, affords a firm basis for articulation with the fulcral plate. The outer plates (*pl.*₂) are considerably wider and shorter than the inner plates, which they dorsally overlap. They measure .35 mm × .19 mm., and are similarly strengthened by a median rib (*r.*₂) in each case. The plates are held in position by means of stout ligaments, each arising from the anterior portion of the inner plate of

its side (*lig.* in Fig. 8). In addition to these elements, a triangular fulcral plate (termed the supporting plate in *Aphelinus*) is present on each side. This structure has its two posterior "angles" rounded so as to form condylar surfaces which articulate with the outer and inner plates of its side. Its remaining "angle" is directed forwards and prolonged into a narrow splint-like process (*prc.*), which is closely attached to the corresponding arm of the stylet. The outer and inner plates of the ovipositor function largely as levers, which work upon the fulcral plate and govern the movements of the stylets and their sheath. A backwardly directed pull exerted by the muscles attached to the inner plate would have the effect of protruding the ovipositor sheath for the purpose of perforating the tissues of the host. By means of a forwardly directed pull, exerted by the muscles inserted on the outer plates of the ovipositor, these lamellæ are brought forwards and downwards. At the same time, this has the effect of tilting the outer angle of the fulcral plate, in such a manner, that the stylets are produced from their sheath, and carried downwards, until they assume a vertical position at right angles to the long axis of the body.

Comparison of the Structure of the Ovipositor with the Sting of the Honey Bee.

If we closely examine the sting of the honey bee, or consult the excellent accounts of the mechanism of the organ given by Cheshire, Packard, Kraeplin, and other writers, it will be observed that its morphology closely agrees with that of the ovipositor of *Blastothrix* and *Aphelinus*. We can, without any hesitation, readily homologise the various elements which together make up the completed organ in the two cases. Furthermore, the method of action of the sting, as interpreted by Cheshire, shows a close agreement with what I believe to be the correct physiological interpretation of the function of the various elements which compose the ovipositor in *Blastothrix*. In the honey bee the so-called palpi or

sting-feelers are represented by the palp-like appendages in *Blastothrix*, and probably most other Chalcids. The inner plates, which basally support these organs, are the homologues of the oblong plates in the honey bee, and similarly the outer plates are homologous with the quadrate plates in the latter insect. The elements which I have termed the fulcral plates in *Blastothrix* perform a similar function to the angular plates of the bee, and the resemblance in form in the two cases is also very close. It is, furthermore, noteworthy that the extremity of the arm of each stylet in both the bee and the Chalcid is closely attached to a process of the angular or fulcral plate of its side. Similarly the sheath or darts are intimately connected with the oblong or inner plate. The general morphology and relations of the sheath and the stylets also agree in their essential features in the two cases.

Size.—Individuals pertaining to the first generation exhibit a comparatively slight range of variation in size. Those of the second generation, however, vary between wide limits. They are, as a general rule, markedly larger than examples belonging to the preceding generation, although in some cases extremely small specimens have been bred out. These, without exception, were obtained from heavily parasitised hosts. The first generation of this Chalcid issues from the larval Coccids when the latter are small, and consequently afford only a restricted amount of nourishment. The imagines of the second generation, on the other hand, have been nourished upon adult hosts, which, unless very heavily parasitised, afford the larval Chalcids very ample supplies of food. It is noteworthy that I have never bred out small examples of the second generation from scantily parasitised hosts. In the light of these observations there is reason to believe that the ruling factor determining size may possibly be the amount of food supply available. In this connection I might recall my previous observations upon *Aphelinus mytilaspidis*, a Chalcid which similarly passes through two annual generations. On p. 255 of my previous paper I men-

tioned that the first generation of *Aphelinus* spends some eight months in the larval stage, and subsists upon the ample food supply afforded by the full-grown adult hosts. In the second generation, however, only three weeks to one month is spent in the larval condition, and each larva has for its sustenance a single immature host averaging 1 mm. long. In *Aphelinus*, therefore, the largest individuals belong to the first generation, while in *Blastothrix britannica* and, I may add, in *Aphycus melanostomatus* also, the largest examples are found in the second generation. These three instances all support the conclusion that food is an important factor determining size. There may be germinal factors also, which are capable of transmission by heredity, but this aspect of the subject is beyond the purport of the present investigation.

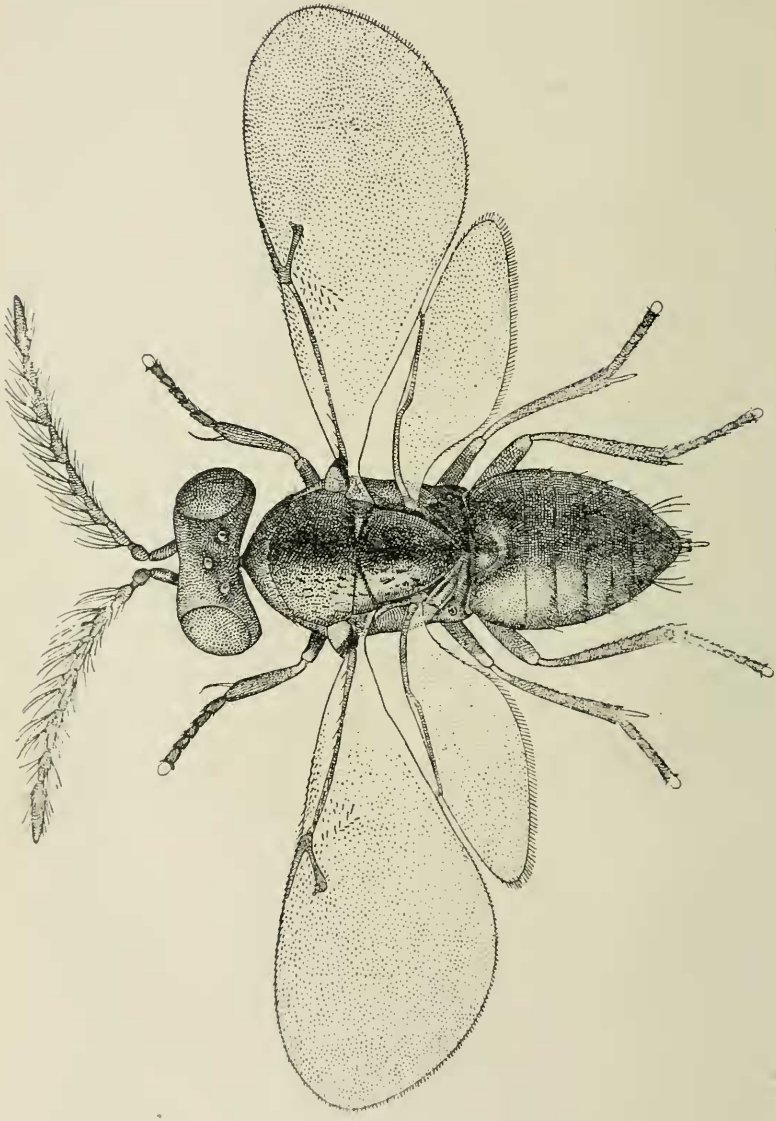
Measurements :

	First generation.		Second generation.
	mm.	mm.	mm.
Length to apex of abdomen	1·84	1·55	2·68
Length of head and thorax	1·04	0·96	1·48
Length of abdomen	0·8	0·59	1·2
Breadth of thorax	0·64	0·56	0·8
Length of fore-wing	1·68	1·44	1·92
Breadth of fore-wing	0·8	0·72	1·04
Length of hind-wing	1·12	0·96	1·44
Breadth of hind-wing	0·33	0·36	0·6
Expanse of fore-wings from tip to tip	4·0	3·44	4·64

(d) The Male.

Observations conducted during 1915 and 1916 showed that the sexes may occur in nearly equal proportions. Thus, out of 44 examples of the second generation bred during 1915 from hosts obtained from Northenden (Cheshire), males and females were reared in equal numbers. In 1916, out of 99 examples of the first generation, bred from material obtained in the same locality, 44 were females and 46 were males. Out of 606 examples of both sexes, obtained from

TEXT-FIG. 9.

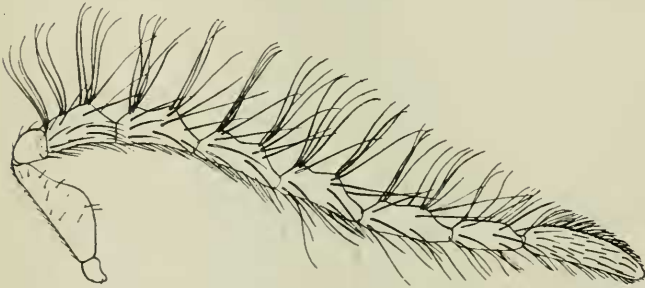


Blastothrix britannica, Gir., male. X circa 48.

various localities during 1915 and 1916, 348 were females and 258 were males.

The following are the principal sexual differences in this species: (1) The males are, as a rule, markedly smaller than the females, although occasionally females are met with which are smaller than exceptionally large males. (2) The antennæ of the males are much paler coloured, and the metallic blue-green reflections are much less evident in the male on the dorsal aspect of the abdomen and on the whole of the ventral surface of the body. (3) The abdomen is smaller and more slender, and it further differs from that of the female in the

TEXT-FIG. 10.

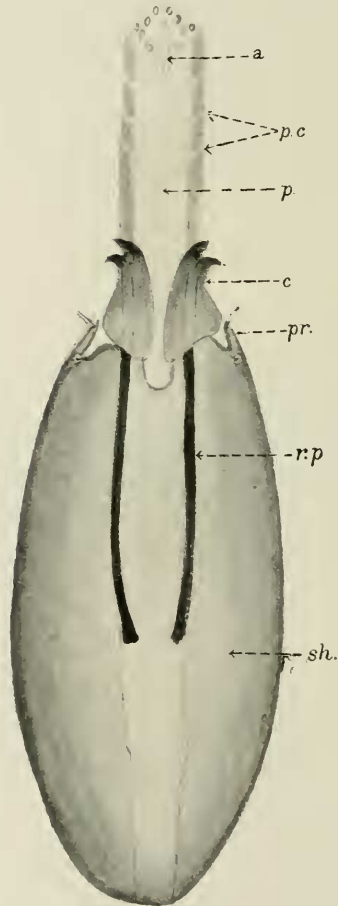


Blastothrix britannica, Gir., male. Right antenna, viewed laterally.

form of the last three segments. (4) The antennæ of the male (Figs. 9 and 10) are composed of 10 joints related to one another in length in the proportions of 2 : 12 : 4 : 6-7 : 8 : 10 : 10 : 10 : 8 : 13-14. The joints between the pedicel and club are deeply incised, and each bears on its dorsal side long, erect, sensory (?) hairs. (5) The external genitalia (Fig. 11). They consist of (*a*) a cylindrical tubular penis (*p.*) tapering at the apex, and measuring .22-.26 mm. in length and .026-.030 mm. in maximum breadth. Basally it is continuous with its sheath (*sh.*), into which it is capable of being retracted very much after the fashion of the finger of a glove. Basally the side walls of the penis are strengthened by a pair of chitinous rods (*r.p.*). That these elements are

actually parts of the penis and not of its sheath is evident from the fact that their position within the latter alters in

TEXT-FIG. 11.



Male genital armature of *B. britannica* seen ventrally. *c.* Clasper (left). *p.* Penis. *p.c.* Pore canals. *pr.* Lateral process. *r.p.* Chitinous rod. *sh.* Sheath of penis. $\times 340$.

accordance with the amount of protrusion or retraction exhibited by the penis. At the apex of the latter organ are

five pairs of minute genital papillæ, which are most probably tactile in function. The tubular investment of the penis is perforated distally by three pairs of pore canals (*p.c.*) having an average width of $\cdot 0027$ mm. Each is closed externally by means of an exceedingly minute spinose papilla (Fig. 12), possibly also of a sensory nature. Arising from the hinder border of the penis sheath, and ventral to the penis itself, is a pair of short claspers (*c.*). These elements are bidentate and freely moveable in the horizontal plane. They measure from $\cdot 035$ to $\cdot 048$ mm. long with an average breadth of $\cdot 016$ mm. Situated externally to the base of each clasper is a small lateral process (*pr.*) which is surmounted by an obliquely and outwardly directed seta. In close association

TEXT-FIG. 12.



Lateral pore canal of the penis of *B. britannica*, highly magnified.

with each process is a minute ventral papilla homologous with a similar structure found in *Aphelinus*.

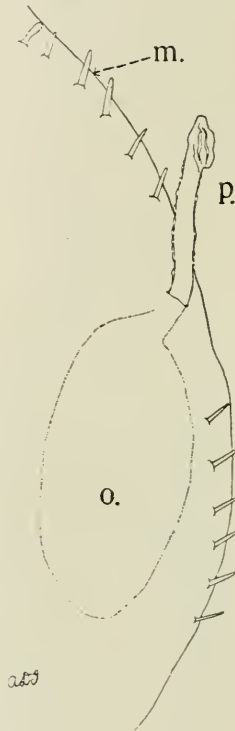
The following measurements are based upon an examination of half a dozen examples selected from each generation; those concerning the wings include the marginal fringe of hairs:

	First generation.	Second generation (two examples).	
	mm.	mm.	mm.
Length to apex of abdomen	1.55	1.04	2.24
Length of head and thorax	1.04	0.6	1.28
Length of abdomen	0.51	0.44	0.96
Breadth of thorax	0.56	0.35	0.60
Length of fore-wing	1.52	1.04	1.72
Breadth of fore-wing	0.72	0.51	0.86
Length of hind-wing	0.92	0.64	1.24
Breadth of hind-wing	0.35	0.24	0.48
Expanse of fore-wings from tip to tip	3.56	2.39	4.04

(e) Oviposition.

Oviposition was observed in the second generation of this parasite at various dates during the end of August and beginning of September, 1916. The observations were conducted

TEXT-FIG. 13.



An egg of *Blastothrix britannica*. Gir., seen in situ beneath the cuticle of its larval host. *m.* Lateral margin of host. *o.* Ovum seen beneath the cuticle of the host. *p.* Pedicel of ovum protruding through the cuticle to the exterior. $\times 250$.

both under laboratory conditions and out in the field. In the laboratory, captured females were transferred to glass cylinders, in which were placed freshly-cut twigs of hawthorn, bearing young *Lecanium* larvæ on the leaves. The cylinders were closed at either end by means of fine bolting-silk, and

the process of oviposition noted under a binocular microscope. The Chalcid first surveys the surface of a *Lecanium* larva by means of the antennæ, and when the ovipositor is brought into position it is inserted into the tissues of the host, only for a relatively short distance. The egg is then placed obliquely into the perforation, with its long axis lying just beneath the body-wall and about four-fifths of the pedicel protruding freely to the exterior (Fig. 13). Parasitised hosts at this stage measured, on an average, $\cdot 8$ mm. \times $\cdot 5$ mm., and are consequently very small. They may be easily recognised by the protruding pedicel just referred to; when viewed by transmitted light the egg of the *Blastothrix* can be recognised beneath the body-wall of the host. The actual position of the egg is tolerably constant, and was specially noted in thirty instances. In all cases the dorsal body-wall of the host was perforated, and in twenty-two examples the egg was placed near the anterior end of the Coccid, close to the margin of the body (Fig. 13). In the remaining cases, it was placed either near the posterior end of the host or between the two extremities of the latter. As a general rule, only one egg is deposited in each host, and, as will be referred to on a later page, the Coccid only affords sufficient nutriment to admit of the development of a single parasite. It was only rarely that two eggs were found in the same individual *Lecanium*, and it is probable that these were laid by two separate females. On still rarer occasions three eggs were present in a single host. What the essential factors are which determine the selection of any particular *Lecanium* larva by this Chalcid I am unable to say. Parasitised hosts appeared to exhibit at this stage no appreciable differences either in size, form, or colour from those which were unattacked.

Females pertaining to the first generation of the *Blastothrix* frequently lay in a similar manner three to nine or more eggs in a single host. This is accountable from the fact that the *Lecanium* is, at that period (May), nearly fully grown, and consequently is able to support numerous parasites.

The significance of this remarkable method of oviposition, which results in the greater part of the pedicel of the egg protruding from the host, is discussed on a subsequent page. Only two other species of Chalcidoidea appear to have been recorded as exhibiting a similar method of egg-laying. Howard and Fiske (1911, p. 180) mention that the long-stalked eggs of *Schedius knvanæ*, How., have their pedicels protruding through the chorion of the eggs of the gipsy moth (*Liparis dispar*), which serve as the host for this species. Furthermore, Timberlake (1913, p. 297) states that *Microterys flavus*, How., lays its eggs in *Coccus hesperidum*, leaving the stalk-like portion projecting through the integument into the outside air.

(f) The Egg.

If examined under a binocular microscope, the eggs of this species may be observed in *sitû* beneath the body-wall of the living host. Owing to the fact that their pedicels protrude to the exterior through the body-wall of the scale-insects, it is a difficult matter to dissect out uninjured eggs. When about one day old¹ the egg is elongate-oval with a smooth, glistening surface, and measures, on an average, $.18 \times .08$ mm. (Fig. 13). At its posterior extremity it is prolonged into a pedicel $.05$ – $.06$ mm. long. This structure soon shrivels at the apex, and its cavity becomes in communication with the outside air—an important fact which is related to the larval respiratory process.

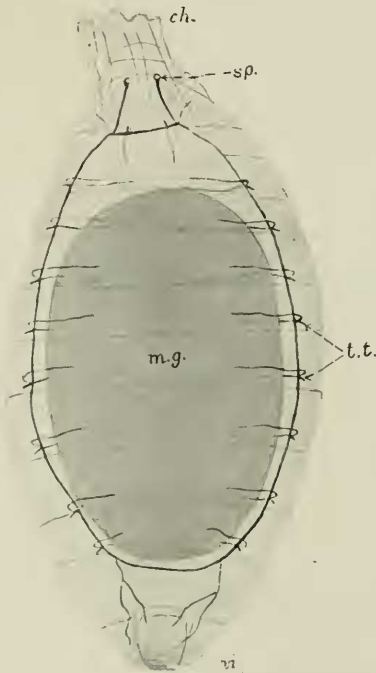
The chorion of the egg admits of a certain amount of extension, and eggs, which contain larvæ nearing the time of emergence, are larger than those freshly laid. In the latter cases the chorion becomes extremely thin, and invests the young larva so closely, that it is often a matter of some difficulty to ascertain whether one is dealing with a newly-emerged larva, or one still enclosed within the egg-shell.

¹ The eggs were dissected out from the body of the host.

(g) The Young Larva.

The smallest larva met with measured .25 mm. long, and differs from the fully-grown larva in its more elongate form, and the rudimentary condition of the tracheal system. It is, moreover, attached by means of the persistent chorion of the

TEXT-FIG. 14.



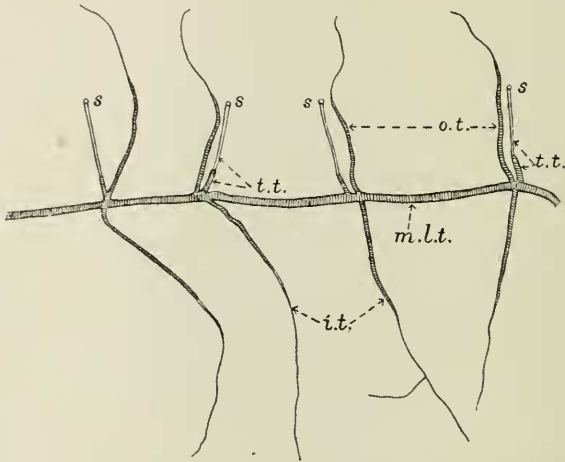
A young larva of *Blastothrix britannica* attached by its caudal extremity to the chorion of the egg; February 15th. 1916. *ch.* Chorion. *hd.* Head. *m.g.* Mid-gut. *sp.* Posterior spiracles. *t.t.* Developing transverse tracheal branches to the spiracles. $\times 116$.

egg to the body-wall of its host. Thirteen segments can be readily recognised, and the tracheal system consists of two thread-like longitudinal trunks united by an anterior and posterior commissure; lateral tracheæ are, as yet, undeveloped.

Larvæ, after the first ecdysis (Fig. 14), measure about

·35 mm. and more in length, and are still attached to the host's body-wall. Their most striking difference from newly-hatched larva is seen in the tracheal system, developing lateral tracheal branches and stigmatic branches being evident (Figs. 14 and 15). A single pair of open spiracles (the ninth) are present. The mandibles are very similar in form to those of the fully-grown larva, but are correspondingly smaller in size. The fat-body is very little developed, and

TEXT-FIG. 15.



Portion of the tracheal system of a living larva of *B. britannica*, ·44 mm. long, showing the first four pairs of segmental tracheae of the right side; March 14th, 1916. *i.t.* Inner segmental tracheal branches. *m.l.t.* Main lateral tracheal trunk of the right side. *o.t.* Outer (dorsal) segmental tracheal branches. *s.* Developing spiracles. *t.t.* Developing transverse tracheal branches to the spiracles. $\times 280$.

the larva is consequently more transparent than it is at a later stage.

(h) The Fully-grown Larva.

Coloration.—Uniformly pearly-white to greyish-white with the food contents of the mesenteron showing through the body-wall as an ovoid lemon yellow mass. The cuticle is colourless, smooth, and shining.

Size.—Measurements were made upon twenty-eight larvæ in the last stage of development, preceding the prepupal condition. The smallest larvæ of the first generation, shortly after moulting, attains an average length of $\cdot 8$ mm.; fully-fed larvæ vary from $1\cdot 04$ to $1\cdot 25$ mm., with a maximum breadth of $\cdot 64$ mm. Larvæ of the second generation are, as a rule, noticeably larger, sometimes reaching a length of $2\cdot 8$ mm.; the smallest larvæ of this generation measured $\cdot 96$ mm.

General Morphology.—In shape the larva does not materially differ from the preceding stage. It may, however, be easily separated from the young larvæ firstly, from the fact that it is no longer associated with the body-wall, but lies

TEXT-FIG. 16.

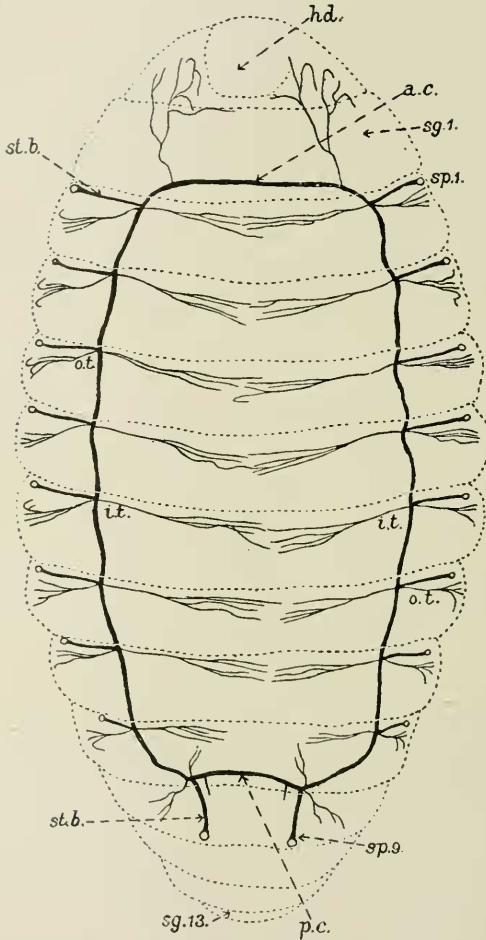


Mandibles of a larva of *B. britannica*, $\cdot 8$ mm. long; March 14th, 1916. Ventral aspect. $\times 670$.

in the body-cavity of its host; secondly, the principal tracheal trunks are of wider calibre, the lateral tracheæ are much more extensively branched, and nine pairs of open spiracles are present.

The larva is divisible into a reduced head region, followed by thirteen trunk segments. The first segment is the largest, the succeeding nine segments are smaller and sub-equal in size, while the remaining segments are much contracted and difficult to make out individually in the living insect. The mandibles (Fig. 16) closely agree in shape with those of younger larvæ; they are, however, rather more strongly chitinised, and measure about $\cdot 05 \times \cdot 03$ mm. The tracheal system (Fig. 17) consists of a pair of main lateral longitudinal trunks, united in the first and ninth segments by

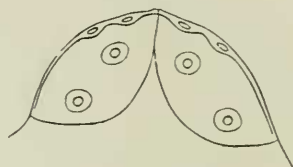
TEXT-FIG. 17.



Tracheal system of a fully-grown larva of *B. britannica*; July 6th, 1916. *a.c.* Anterior commissure. *hd.* Head. *i.t.* Inner segmental trachea. *o.t.* Outer ditto. *p.c.* Posterior commissure. *sg. 1.* First trunk segment. *sg. 13.* Thirteenth ditto. *sp. 1.* First spiracle (right). *sp. 9.* Ninth ditto. *st.b.* Spiracular or stigmatic branch.

means of anterior and posterior commissures respectively (*a.c.* and *p.c.*). From the anterior commissure a pair of tracheal branches takes its origin; these tracheæ bifurcate in the first segment, and ultimately subdivide into a series of smaller branches, which are mainly distributed in the head. Nine pairs of spiracles are present, and are situated on the second to tenth segments inclusive. Those of the ninth pair are somewhat larger than the preceding spiracles; they are, moreover, dorsal rather than lateral in position, and open into rather longer stigmatic branches (*st.b.*). In each spiracle-bearing segment a pair of lateral tracheæ are given off on either side. One branch (*i.t.*) arises from the main lateral

TEXT-FIG. 18.



Oral lobes and papillæ of a larva of *B. britannica* in the peripneustic stage: April 4th, 1916. \times circa 500.

trunk of its side opposite the point of junction with the segmental stigmatic branch; this branch is directed inwards, and its tracheoles are mainly ventral in distribution. The other branch (*o.b.*) takes its origin either from the base of the stigmatic branch of its side or at the point of union of that branch with the main lateral trunk. It breaks up into tracheoles, which are mainly dorsal in their distribution.

The fully-grown larva of this species may be separated from that of *Aphycus melanostomatus* by the following among other characters: (1) Its more elongate form; (2) the lemon yellow colour of the contents of the mid-gut; (3) the mandibles being] more curved at their apices; (4) the hindmost segments of the body are contracted, and not easily separable individually; (5) the larger size of the ninth pair of spiracles and its more dorsal situation on its segment.

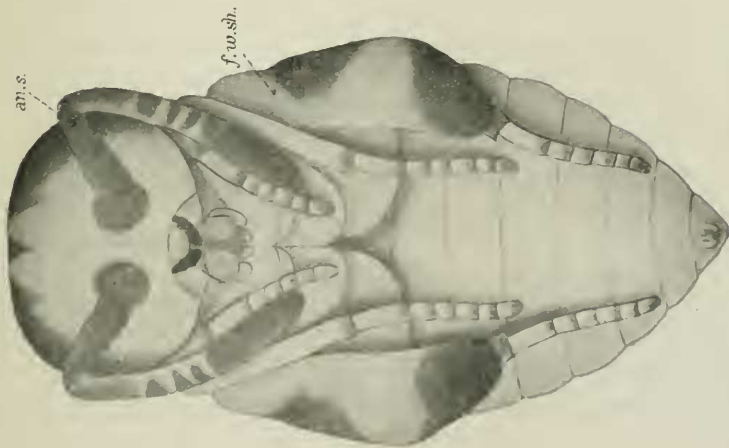
(i) The Pupa.

Coloration.—When newly formed the pupa is glistening white, but the various parts assume a smoky-grey colour very early in pupal life. This suffusion involves the dorsal surface first, apparently owing to its being nearest the light. Later, the grey coloration extends to the ventral surface also. The intersegmental, and other feebly chitinised areas, remain white until near the close of the instar. The eyes are dull brown, darkening gradually until they become almost black. About eight days prior to the emergence of the adult Chalcid, the pupa becomes almost entirely black with the exception of greenish reflections on the head; the wing sheaths, however, are whitish, with basal and apical suffusions (Fig. 19).

Size.—Pupæ of the first generation measure from 1·5 to 1·7 mm. in length and ·7 to ·9 mm. in breadth across the wing sheaths. Those of the second generation are often distinctly larger and more variable in size, male pupæ measuring from 1·6 to 2 mm. in length and from ·7 to 1·1 mm. in breadth across the wing cases. Female pupæ measure from 1·7 to 2·5 mm. long and ·9 to 1·3 mm. in breadth.

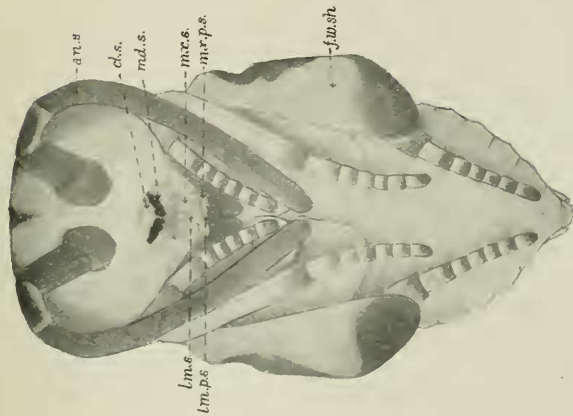
Morphology.—The sex of an individual pupa can be readily determined by the fact that in the male the antennal sheaths are longer and somewhat more slender than those of the female (Figs. 19 and 20). The genitalia also offer a second though less obvious criterion. Seen from the dorsal aspect (Fig. 21) the head, thorax, and abdomen are mutually related in length in the approximate proportion of 2:9:9. The antennal sheaths (*an.s.*) are partially visible laterally in the female; in the male they project forwards in front of the eyes and curve round the sides of the head, thus exhibiting a greater portion of their length to view. The thorax is divided into three conspicuous areas—the pronotum, mesoscutum, and mesoscutellum. The sheaths of the forewings (*f.w.sh.*) are visible laterally to as far back as the commencement of the second abdominal segment. In the abdomen seven segments are clearly distinguishable. On the

TEXT-FIG. 19.



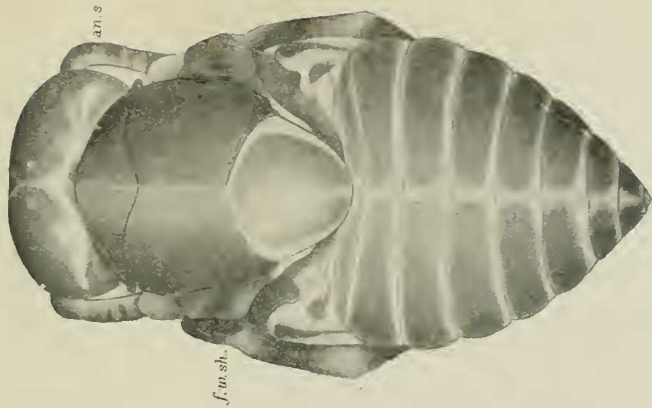
Female pupa of *B. britannica*, ventral aspect. Reference lettering as in Text-fig. 21. $\times 55$.

TEXT-FIG. 20.



Male pupa of the same species, ventral aspect. *an.s.* Antennal sheath. *cl.s.* Sheath of clypeus and labrum. *f.w.sh.* Sheath of fore-wing. *lm.s.* Labial sheath. *lm.ps.* Sheath of labial palp. *md.s.* Sheath of mandible. *mx.s.* Maxillary sheath. *mx.ps.* Sheath of maxillary palp. $\times 55$.

TEXT-FIG. 21.



Female pupa of the same species, dorsal aspect. *an.s.* Right antennal sheath. *f.w.sh.* Sheath of the left fore-wing. $\times 55$.

ventral aspect (Figs. 19 and 20) the following features are most evident. The antennal sheaths (*an.s.*), as is usual among Chalcids, are markedly elbowed. Their basal or scape portions are inclined upwards and outwards, and their points of insertion on the head are separated by an interval equal in width to the scape at its broadest point. The flagellum is inclined backwards and inwards; in the female it is swollen terminally and does not reach the apices of the sheaths of the first pair of legs. In the male the antennal sheaths are longer and more slender than in the female, and, moreover, they extend backwards to the apices of the first pair of legs. The mandibular sheaths (*md.s.*) are situated a short distance behind the bases of those of the antennæ. That of the clypeus (*cl.s.*) is sub-triangular and partially overlies the mandibular sheaths. Two maxillary sheaths are present on either side. One, a broad common sheath (*mx.s.*), encloses the body of the maxilla of its side. The other (*mx.p.s.*) encloses the maxillary palp; it has a broad flattened apex and is external in position. The labial sheath (*lm.s.*) is quadrangular and lies between the bases of the maxillary sheaths (*mx.s.*). At its apex is a pair of short broad sheaths (*lm.p.s.*), enclosing the labial palpi.

(j) Life-history.

Methods of Investigation.—For the purposes of this research three methods were resorted to: (1) Material consisting of shoots and young branches of hawthorn, bearing the host *Lecanium*, was collected from numerous localities, and any parasites present were bred out. The hawthorn shoots were cut up into convenient lengths and the cut ends sealed up by dipping into molten paraffin wax. They were then placed in the same type of breeding-cage as was utilised in my previous study of *Aphelinus* (Imms, 1916, p. 248, text-fig. 2). The parasite breeding-cages were placed in the open insectary which has already been described and figured (*loc. cit.*, p. 247, text-fig. 1). By this means the parasites were reared as far as possible under out-of-door conditions. (2)

Over 600 examples of the host Coccid were collected at frequent intervals from various localities in the field and dissected under a binocular microscope in the laboratory. By this means a tolerably complete series of stages in the life-history of the *Blastothrix* was obtained. (3) Nine young, well-grown bushes of hawthorn (*Cratægus oxycantha*) were planted in the University of Manchester Biological Experiment Ground at Fallowfield. These were thoroughly searched for the presence of any examples of the *Lecanium*, but were found to be quite free from that Coccid. A wooden framework was erected over these plants and ordinary netting, of small mesh, similar to that used to protect fruit bushes from the attacks of birds, was fastened over the sides and roof; entry to the interior of the cage was gained through a door situated in the middle of one side. By means of this cage tits and other birds which prey upon Coccidæ were excluded. The hawthorn bushes were subsequently experimentally infected with *Lecanium* and its parasites.

The First Generation.—The first generation of adult *Blastothrix* is derived from larvæ which have passed the winter within the bodies of the larval *Lecania*. When the time arrives for the emergence of the parasites, the hosts are small, measuring on an average from 1.5 to 2 mm. in length and from .9 to 1.25 mm. broad. They are invariably dead, and all that remains of the former insect consists of the dried integument together with its dorsal scaly covering. When about to emerge, the *Blastothrix* cuts a neat hole by means of its mandibles through the scales of its defunct host. The aperture is median and dorsal in position (Fig. 22), though usually situated nearer to the posterior than the anterior extremity of the scale, and may be readily seen with the unaided eye. When the parasite issues through the emergence hole its wings and other appendages are fully formed, and, after devoting a short interval to preening itself, the insect flies away to seek its impressions of the outer world. The earliest observed date of emergence was May 3rd, and the insects continued appearing in the breeding-cages until

June 2nd. As a general rule, males appear at first in greater abundance than the females, the latter subsequently increasing in numbers. Sexual reproduction was found to invariably occur, no instance of parthenogenesis being observed. The eggs are laid during the latter half of May and the beginning of June, and the general details of oviposition have already been described (p. 320). At this period the hosts have assumed their globular berry-like form and are fully grown. The young parasitic larva upon hatching out from the egg remains in close association with the ruptured chorion of the

TEXT-FIG. 22.



A young larva of *Lecanium capreae*, showing the emergence hole made by *Blastothrix britannica* (first generation).
 × circa 12.

latter, its posterior extremity lying at the base of the pedicel. By this means it is enabled to freely breathe the atmospheric air through the open apex of the pedicel, and the significance of its metapneustic tracheal system therefore becomes evident. As regards feeding habits, the larva is at first largely hæmophagous, feeding freely upon the blood plasma of its host. From a study of the serial sections, made through the larva in situ within the Coccid, it is evident that it subsequently devours as much of the surrounding fat-body as lies within its reach. Two ecdyses have been observed, and the process of casting the skin is an extremely gradual one. During

growth the original cuticle becomes more and more stretched until it ruptures near the anterior extremity of the body. The old skin is gradually sloughed off backwards, until its shrivelled remains are to be found around the tail end of the larva. In almost all cases, the cast-off mandibles may be found after a careful search among the remains of the old cuticle.

The ecdysis having been passed through, the larva is still attached to the chorion of the egg, and, although the tracheal tubes are now of larger calibre, and exhibit more extensive ramification of the tracheoles, only a single pair of meta-pneustic spiracles are present. Subsequently the larva loses its attachment to the chorion and comes to lie free in the body-cavity of its host. In feeding habits it is steatophagous, devouring the fat-body of the Coccid. At this stage it varies very greatly in size, some larvæ measuring .9 mm. long, while others may exceed a length of 2 mm. The latter are usually about to undergo a further ecdysis, which takes place in a similar manner to that undergone previously. The remains of this later moult are to be detected, along with the cast-off covering of the jaws, in close contact with the previous skin at the hinder end of the body. It appears, therefore, that the old larval skins are not completely cast off. In this connection it is noteworthy that Newport (1855, p. 73, pl. viii, fig. 16) detected three successive cast skins at the posterior end of the body in the larva of the Ichneumon *Paniscus virgatus*, Fourc. After this latter moult, the larva of the Blastothrix becomes peripneustic (Fig. 17), with nine pairs of spiracles. This latter condition is a further adaptation to changed circumstances. The host at this stage contains a good deal of free air among its tissues, and probably air is liberated by the laceration of the smaller tracheal branches by the mandibles of the parasite during its search for food. When the fat-body is entirely devoured, the larva becomes sarcophagous, and commences to devour the various internal organs, ultimately bringing about the death of its host.

The number of parasites harboured by any individual

example of *Lecanium capreæ* is subject to a wide range of variation. Hosts containing a single parasitic larva are frequent; but, on the other hand, large numbers of the latter may often be present within a single Coccid. The greatest number of the *Blastothrix* larvæ found in any one individual host was forty-two, all of which were fully fed, and some had already assumed the prepupal condition.

Not infrequently the older larvæ in the body-cavity of the host are enclosed in a kind of enveloping sheath or envelope. In other instances, the larvæ are entirely free, no such investment being present. From an examination of numerous serial sections, it is evident that the sheath is composed entirely of host tissue. When stained with hæmatoxylin and eosin it is markedly eosinophilous, and is seen to be composed very largely of dead, ill-defined tissue devoid of definite cell-boundaries, and with nuclei only very occasionally evident. Tracheæ are frequent, and fine branches pass from neighbouring tracheal vessels and terminate in the walls of the sheath. Scattered through the substance of the latter, are numerous conidia of a fungoid nature, similar in every way to those which are constantly present in the fat-body and other tissues of the host. The pupæ are not infrequently found enclosed in a membranous cocoon-like structure which appears to be nothing more than the dried remains of the sheath within the dead host.

When fully fed, the larva discharges the contents of the alimentary canal, which are usually observable as small ovoid brown pellets, clustered around the posterior region of the pupa; no excretory matter was voided earlier in life, and, in fact, its presence would scarcely fail to act deleteriously on its host, and possibly involve both the death of the latter and its parasite. The time spent as a larva varies from about three to four and a half weeks. The earliest pupæ were met with on June 23rd, and they may be found within the hosts up to about the middle of August. The pupal stage lasts from twelve to twenty-three days, the length of time spent in this stage depending upon current climatic conditions.

Parasitised hosts cannot be recognised by any invariable symptoms; when only a single parasite or a very small number are present, within any individual host, it is often impossible to detect their presence unless the latter is carefully dissected. On the other hand, certain unmistakable indications of parasitism are frequently evident. The hosts very often lose some of their rounded berry-like form, and have a less regular and somewhat humped appearance. This is due to the presence of parasites near the surface of the body-wall, which causes the latter to bulge externally. The *Lecanium* (*Coccus*) *gibberum* of Dalman is only a parasitised *Lecanium capreæ*, characterised by the presence of two large mammiform swellings on the sub-dorsal region. The swellings are very irregular in size, some being scarcely visible, while others are very pronounced (Newstead, 1893, p. 108). Frequently parasitised hosts are much paler in colour than unaffected examples, and markedly translucent, with the integument harder and more brittle. This change in appearance is due to the excavation of the underlying tissues by the larval parasites, thus rendering the integument more transparent than it would otherwise be.

It is a remarkable fact that the first generation of this parasite exercises very little effect upon the fecundity of its host, death of the latter seldom occurring until after it has deposited its ova. Some 225 female hosts, of as nearly as possible uniform size, were collected at Northenden (Cheshire), a few days before the larval *Lecania* commenced to issue from the egg. The eggs were carefully removed from beneath each scale, and dropped into a fine glass tube graduated into millimetres and filled with alcohol. As soon as all the ova had settled down their quantity was judged by the graduated scale. This method gave approximately accurate results, but it involved a great deal of time transferring the eggs to the tube by means of a camel-hair brush. Subsequent dissection of the hosts proved that 132 were parasitised; of these no less than 94 examples (71·9 per cent.) laid what was estimated to be approximately the normal quantity of eggs;

29 (21·9 per cent.) individuals laid no eggs at all, and 9 (6·8 per cent.) individuals laid less than the normal quantity of eggs. From among the ninety-three unparasitised hosts, 47 (50·5 per cent.) laid about the normal quota of eggs; 39 examples (41·9 per cent.) laid no eggs at all, and 7 examples (7·5 per cent.) laid less than the usual quantity of eggs. It is further noteworthy that 15 out of the 94 parasitised hosts, which laid the normal quantity of eggs, supported no less than 18 to 42 parasites apiece. It is remarkable that in spite of being so heavily parasitised oviposition was carried out without interruption. A number of the eggs were kept under observation and hatched into larvæ in the usual time. The fact that twenty-nine parasitised hosts deposited no eggs at all, affords no certain evidence that the presence of the *Blastothrix* larva exercises an inhibiting effect upon oviposition. This conclusion is supported by evidence derived from an examination of unparasitised hosts, 42 per cent. of the latter failing to lay any eggs. It is difficult to account for these facts except upon the supposition that they were unfertilised individuals, as the male *Lecanium capreæ* is much scarcer than the female.

In the vast majority of instances the *Lecanium* is attacked by the first generation of the parasite so late in life that little or no interference with egg production occurs. The *Blastothrix* larvæ only assumes the sarcophagous habit at a time when their hosts have laid the greater number of their ova.

The Second Generation.—On June 30th, 1914, while examining some parasitised *Lecania* I observed movement beneath the integument of one of the Coccids. It proved to be due to an example of the *Blastothrix* which was endeavouring to effect its entry to the exterior. In a short time it was seen to perforate the covering of the scale insect by means of its mandibles (at 11.10 a.m.). By cutting a successive series of sausage-shaped pieces from the body-wall it succeeded in making a round and clean emergence hole through which it issued just thirty minutes later (Fig. 23). It immediately crawled away, making no attempt to fly. The

earliest date of emergence was June 23rd, and the last male appeared on July 30th; females continued to emerge until August 25th. At first males appear in greater abundance than the females; out of 481 bred males, 67 (13·9 per cent.) emerged between June 23rd and 30th; 240 (49·8 per cent.)

TEXT-FIG. 23.



Two fully-grown Scale insects (*Lecanium capreae*) with numerous emergence holes made by the parasitic Chalcid dealt with in this paper. The two larger holes in the upper specimen were made by *Blastothrix britannica*; the remaining smaller holes are due to *Aphycus melanostomatus*. $\times 8$.

between July 1st and 7th; 108 (22·4 per cent.) between July 8th and 14th; 50 (10·3 per cent.) between July 15th and 21st; 16 (3·3 per cent.) between July 22nd and 30th. From among 435 bred females, 21 (4·8 per cent.) emerged between June 23rd and 30th; 92 (21·1 per cent.) between July 1st and 7th; 104 (24·1 per cent.) between July 8th and 14th; 156

(35.8 per cent.) between July 15th and 21st; 53 (12.1 per cent.) between July 22nd and 31st; 9 (2 per cent.) between August 1st and 25th.

An important factor in the life-history of the two generations of the parasite is the size of the host. The first generation lays its eggs in the fully-grown host, which may support upwards of fifty individual parasites. When the second generation deposits its eggs the host is in the condition of a very young larva, attached to the underside of the leaves of its food-plant, and never finally supports more than a single parasite. If more than one egg is laid therein, only one of the parasitic larvæ ever comes to maturity. Oviposition takes place over a lengthy period, during a prevalence of warm and sunny weather. It was observed at the end of July, and females have been noticed laying their eggs as late as the first week in September. Unhatched eggs have been found in the host up to November 7th. The young larvæ upon emerging remain associated with the chorion of the egg, respiring through the pedicel of the latter throughout the winter months. Its habits and metamorphosis are very similar to those already described with reference to the first generation. Towards the end of the winter the larvæ attain an average length of .7 to 1.2 mm., lose this attachment, and come to lie free in the body space of their hosts. The earliest larva in this condition was observed on February 15th, 1916, but it was not until the middle of March that free larvæ became numerous. When fully fed the larva voids the contents of the alimentary canal in the form of light brown pellets, which are discharged in such a manner as to form a chain on either side of the body, and are clearly visible through the integument of the host (Fig. 24). It is about this time that the parasite turns completely round inside the host. Hitherto, in the majority of cases, the head of the larva was directed towards the anterior extremity of the host, but its position now becomes reversed—a curious fact which has also been noted by Miss Embleton (1904, p. 243) in larva of *Comys infelix* which parasitises

Lecanium hemisphæricum. Pupæ were first observed in 1915 on April 19th, and in 1916 on May 1st, and commence to occur abundantly about the middle of the latter month. The pupa fills the greater part of the body space of its host (Fig. 24), and lies with its dorsal surface upwards and its head end directed toward the posterior extremity of the Coccid; occasionally, however, pupæ are found with the head pointing in the opposite direction. The period spent in the pupal stage varies approximately from four to seven weeks, but it is very dependent upon prevailing climatic

TEXT-FIG. 24.



Enlarged figure of a young larva of *Lecanium capree* containing a pupa of *Blastothrix britannica*. The anterior extremity of the latter is directly toward the anal end of the host. The ovoid opaque bodies are excrementa ejected by the larval parasite prior to pupation.

conditions and may be prolonged or curtailed accordingly. Examples which pupate early in May were observed to spend a much longer period in that condition than larvæ which delayed pupation until June.

The effects of the second generation of parasitism upon the host always lead to the death of the latter. When first parasitised the larval Coccids betray no symptoms of being affected and continue to grow normally. Apart from actual dissection, the presence of the parasite at this stage can only be detected by searching for the pedicel of the egg, which protrudes through the body-wall. After the winter the parasites have grown con-

siderably, and the older they become the clearer do their hosts exhibit symptoms of parasitism. By the month of April affected hosts are, as a rule, smaller than unattacked examples, and may usually be readily recognised by their uniform yellowish-brown or brown colour. The presence of the parasite causes the Coccid to become swollen and somewhat distended, and, by examining the host from the ventral surface, the parasitic larva can be frequently detected through the thin membranous body-wall. Occasionally the hosts are distorted in shape, or exhibit a mammiform bulging, owing to the pressure exerted by the parasite while it was still attached to the chorion and lying close beneath the body-wall.

The most important biological feature in the life-history of this Chalcid is the presence of a metapneustic tracheal system in the young larva, which is intimately correlated with direct respiration of the atmosphere through the medium of the pedicel of the egg. This species affords the first described case of the occurrence of a metapneustic larva among the Hymenoptera. It, furthermore, presents an interesting example of convergence towards a condition which is very general among parasitic larvæ belonging to the Diptera Cyclorrhapha. Keilin (1915) has discussed at length the essential differences between the endoparasitic larvæ of the Diptera and Hymenoptera. In an extremely able essay this observer takes into consideration both biological and morphological characters, and emphasises the fact that the primary larvæ of parasitic Diptera are metapneustic, with their spiracles in free communication with the air. He contrasts this condition with that found among Hymenoptera, and points out that Scurat (1899) has shown that the young parasitic larvæ of that order are apneustic. The cuticle investing the general surface of the body is extremely thin, and it is by means of cutaneous respiration that those larvæ derive their oxygen from that dissolved in the blood-tissue of their hosts. It is evident, therefore, that the life-history of *Blastothrix* presents an exception to this generalisation, and that other metapneustic hymenopterous parasites remain to be dis-

covered in the future. The method by which the larva of *Blastothrix* gains communication with the free air is, however, totally different to that which obtains among the "larves entomobies" of those Diptera studied by Pantel and others. Among the latter insects their larvæ gain access to the air either by perforating the skin of the host, or by boring through the wall of a tracheal trunk, and acquiring an intimate secondary connection therewith.

OBSERVATIONS ON *APHYCUS MELANOSTOMATUS*, TIMB.

(a) Systematic Position.

Aphycus melanostomatus is a member of the Chalcid sub-family Encyrtinæ, which is included within the extensive family of the Encyrtidæ. The Encyrtidæ may be readily recognised by the stout saltatorial spur to the middle tibiæ and the large non-impressed mesopleura. The sub-family Encyrtinæ is distinguished according to Ashmead (1904, pp. 286-87) by the following characters: The mesonotum is entire, convex or sub-convex, and the parapsidal furrows are totally absent. The marginal vein is rarely very long, often punctiform, and always much shorter than the sub-marginal or sub-costal vein; the stigmal vein is usually short, rarely long. The scutellum is never short or transversely linear, and the middle tibiæ are devoid of lateral spines.

The genus *Aphycus* was erected by Mayr in 1875 (p. 695), who also pointed out the essential differences between the males and females. The characteristics of the females as enumerated by Howard (1881, p. 364) are as follows: The antennæ are short, two-jointed, and inserted close to the mouth; the scape is broadened or cylindrical, with the pedicel just about twice as long as thick; the joints which follow the pedicel gradually increase in thickness, and, moreover, are thicker than long; the club is about equal in length to the three preceding joints, obliquely rounded, and often flattened. The face, vertex, and dorsum of the thorax are devoid of lustre, finely punctured, and are frequently clothed with

yellowish hair. The marginal vein is undeveloped, and the stigmal vein is given off at the junction of the sub-costal with the costa. A more detailed diagnosis of the genus will be found in the recent memoir by Timberlake (1916, p. 587).

The males may be distinguished by their more slender antennæ, with the scape less widely dilated below, the flagellum more pubescent, and the club devoid of any traces of jointing.

According to Schmiedenknecht (1909, p. 240), thirty-four species of *Aphycus* were known at the time of his generic monograph. Richardson (1916) brings the total up to forty-three, but of these four or five species are somewhat doubtfully included within the genus.

(b) Habits and Distribution of the Genus *Aphycus*.

The vast assemblage of Chalcids which are included in the family Encyrtidæ live as parasites of the ova, larvæ, or pupæ of other insects, and hardly a single order of that group of animals is immune from their attacks. As Ashmead remarks (1900, p. 323): "In this family, and more especially in the sub-family Encyrtinæ, the species are of more than ordinary interest and importance, since so many of them are found attacking and destroying the scale- and bark-lice (Coccidæ and Aleyrodidæ) and the plant-lice (Aphididæ and Psyllidæ), containing some of the most destructive and troublesome pests with which fruit-growers, agriculturists, and florists have to contend."

The various species of *Aphycus* are parasites of Coccidæ (scale insects), and chiefly attack members of the genus *Lecanium*. Several species also parasitise *Pulvinaria*, *Ceroplastes*, and *Coccus*; other forms have been occasionally bred out from species of *Saissetia*, *Physokermes*, *Lichtensia*, *Eriococcus*, *Filippia*, and *Tourmeyella*.

The genus *Tachardia* has also been recorded as a host, but this statement should be received with reservation. It is, furthermore, noteworthy that *Aphycus annulipes*

(Ashm.) has been recorded by Ashmead as a parasite of the coleopterous insect *Attelabus bipustulatus*. I am informed, however, by Dr. L. O. Howard that this record is a very doubtful one, and it is impossible now to ascertain the conditions under which the late W. H. Ashmead reared the species. *Aphycus chrysopæ*, Ashm., which was bred out from an undetermined species of the neuropterous genus *Chrysopa*, is placed by Schmiedenknecht (1909, p. 236) in the allied genus *Isodromus*. There are consequently no undoubted records of a species of *Aphycus* utilising any insects other than Coccidæ for their hosts. No detailed study of the biology of any species of the genus has so far been published, but it is evident that the latter includes both ecto- and endo-parasites. According to Mercet (1916, p. 776), *Aphycus hesperidum*, Mer., is an ectophagous parasite, while the species dealt with in the present paper lives within its host. The occurrence of two different modes of larval life among parasites of the same genus is by no means unique, since it is also exhibited, for example, among species of *Aphelinus*.

Aphycus is a genus whose species are known from many regions of the world, including most countries of Europe, also North and South America, Sandwich Islands, Philippines, South Africa, Australia, New Zealand, Ceylon, China, Japan, and the West Indies. Although the greater number of the known forms have been recorded from North America, this fact is mainly due to the importance attached to the study of parasites in the United States. When the European forms have been collected equally assiduously, it is probable that they will not fall far short in point of numbers.

Only two species, viz. *A. hederaceus* (Westw.) and *A. pappus* (Walk.), are listed by Morley (1910, p. 22) as being British insects. *A. pappus*, however, is retained by Schmiedenknecht (1909, p. 245) in its original genus *Encyrtus*, to which it was relegated by Walker. This species is also not included by Timberlake in his recent revision of *Aphycus* and closely allied genera. Walker

(1838, p. 108) records *A. hederaceus* as being found on grass beneath trees near London, and at Holywood, near Belfast. *A. melanostomatus* is the only other British species, and has been recently described by Timberlake¹ (1916, p. 608), who mentions (p. 610) that it occurs in Denmark and England. Danish examples were reared by Kryger from a species of *Lecanium* growing on lime at Ermelunden and on oak at Dyrehaven. The English specimens were reared by Douglas in 1890 from *Lecanium fuscum*² (Gmelin) growing on oak. I know of no further records of this insect. During the years 1914-17 I have bred out this Chalcid from examples of *Lecanium capreae* obtained from the following localities: Lancashire: Fallowfield and West Didsbury, near Manchester. Cheshire: Northenden, Ashley, Knutsford, and Lymm. Derbyshire: Edale, Castleton, Whaley Bridge, and Lathkil Dale. In each locality the species occurred plentifully, and did not appear to be at all local in distribution.

(c) The Female.

Coloration.—Black, extensively marked with orange-brown and yellowish-white. The scape of the antenna black, with a narrow line along its upper margin, and a rounded spot on the outer surface at the proximal extremity, yellowish-white; the proximal half of the pedicel, the first three joints of the funiculus and the club black; the distal portion of the pedicel and the remaining joints of the funiculus yellowish-white, the funicular joints usually with a variable amount of smoky suffusion. The head between the eyes orange-yellow, with the occipital region black, which extends laterally until it expands into a conspicuous area at the lower angle of the cheeks on

¹ Timberlake (1916, p. 608) gives the following synonyms for this species:

Encyrtus punctipes. Dalman (part), Svensk. "Vet.-Akad. Handl.," vol. xli, 1820, p. 371.

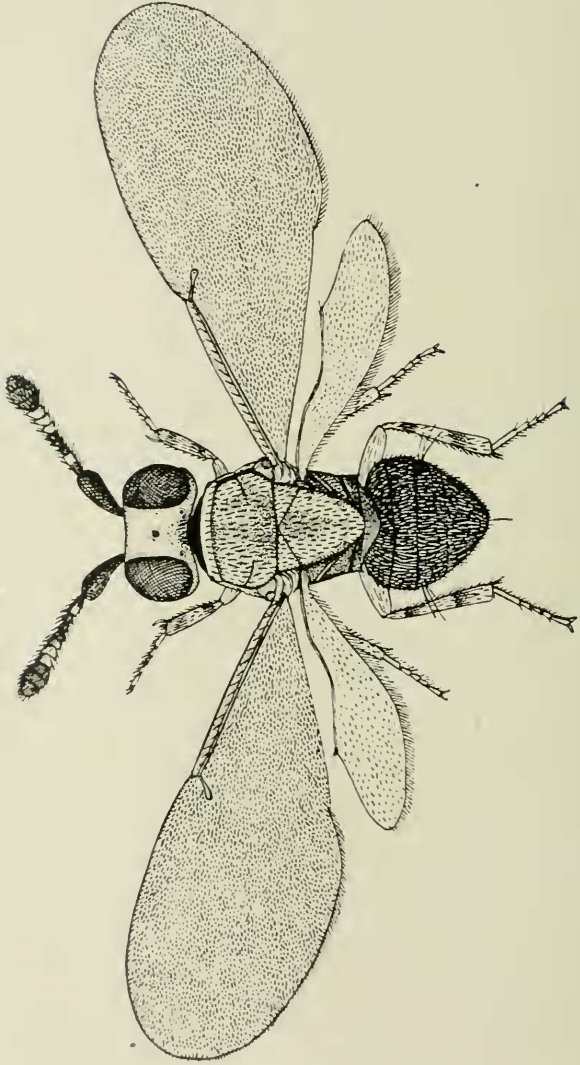
Encyrtus punctipes, var. 2, Nees, "Hym. Ichn. affin. Monogr.," vol. ii, 1834, p. 202.

² A synonym of *L. capreae*.

each side; the remainder of the head yellowish-white faintly tinged with pink; the eyes leaden-coloured or primrose when fully pigmented. The concealed portion of the pronotum black, the remainder whitish with a small dark-brown spot near its outer edge on each side. The mesonotum orange-yellow, with the anterior margin deeply suffused with black. The metanotum, propodeum, and the dorsal surface of the abdomen black. The legs yellowish-white or pale straw-coloured, the tibiæ with two to three smoky annulations and the last tarsal joint also smoky. The wings hyaline with the nervures pale yellowish-brown. Ventrally the insect is mostly yellowish-white.

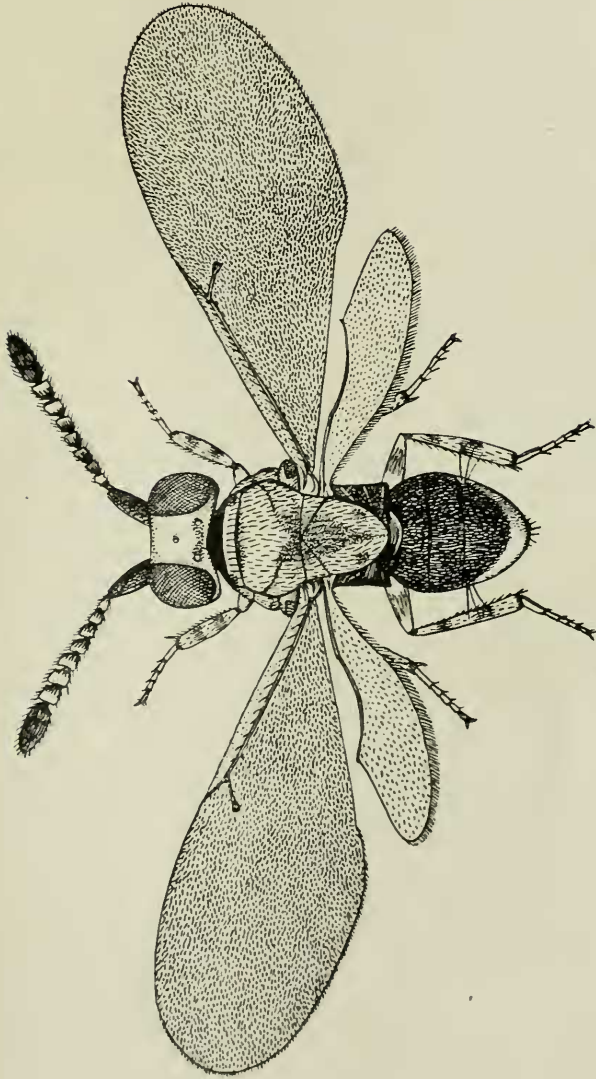
Individuals agreeing with the above description (and also with Timberlake's diagnosis) are to be regarded as being typical for the species. During the present investigations, however, three well-marked, colour variations were frequently met with and have not hitherto been described. These may be most conveniently referred to as follows:—Variety α : In this variety the whole or the greater portion of the bright orange coloration of the mesonotum is replaced by dark brown, and the antennal joints beyond the pedicel are uniformly black. Variety β : This agrees with the preceding variety, with the exception of the antenna, which exhibit the normal typical coloration. Variety γ : In this variety the normal coloration of the species is retained, with the sole exception that the antennal joints beyond the pedicel are uniformly black as in variety α . Although these varieties are, for the most part, sharply defined, occasional individuals intermediate in colour between the vars. α and β and the type were found, and also examples intermediate between the vars. β and γ . This fact, together with the absence of any structural differences, removes, in my opinion, any valid reason for elevating them to specific rank. It is, furthermore, noteworthy that typical females, together with individuals pertaining to these three varieties, have been repeatedly bred out from hosts obtained from various localities. None of these varieties are confined to any one locality or generation.

TEXT-FIG. 25.



Aphyeus melanostomatus, Timb., female. X circa 45.

TEXT-FIG. 26.



Aphyeus melanostomatus. Timb., male. X circa 46.

From among 151 examples of this parasite which were specially examined with reference to their coloration, only 44 (or 29 per cent.) were typical in every respect; 30 (or 19 per cent.) belonged to the variety α ; 51 (or 33 per cent.) were of the variety β , and 26 (or 17 per cent.) belonged to the variety γ .

The accompanying measurements were taken from an average-sized example selected from each generation:

	First generation.	Second generation.
	mm.	mm.
Length to apex of abdomen . . .	1.12	1.51
Length of head and thorax . . .	0.68	0.8
Length of abdomen	0.41	0.71
Breadth of thorax	0.42	0.55
Length of fore-wing	1.31	1.56
Breadth of fore-wing	0.56	0.7
Length of hind-wing	0.88	0.96
Breadth of hind-wing	0.25	0.32
Expanse of wings from tip to tip .	3.04	3.6

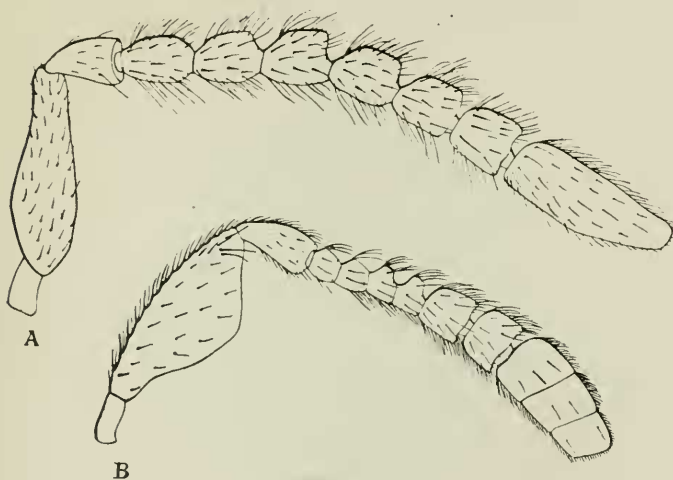
(d) The Male.

The males are less numerous than the females: out of 49 examples of the first generation bred from two localities 8 were males and 41 females. From among 549 specimens of the second generation 131 were males and 418 females. The proportions of the sexes differed from different localities as follows: Northenden, 36 males, 238 females; Ashley, 63 males, 94 females; Marple, 20 males, 35 females—the approximate proportion of males to females in this generation being 1:3.

The male insect may be readily distinguished from the female by the following characters: The front and vertex of the head are wider than long; in the female these parts are distinctly longer than broad (Figs. 25 and 26). The antennæ (Figs. 27A and 27B) are pale yellow-brown and rather longer than the female. The scape is much narrower than in the latter sex, being about three times as long as broad; the pedicel is a trifle shorter than the first joint of the funiculus; the funicular joints are all sub-equal in length, and

the club is unjointed and longer than in the female. In the latter sex the scape is approximately one-half as wide as long and the pedicel more than twice the length of the first joint of the funiculus; the first four funicular joints are sub-equal in length, but the remaining two are distinctly larger; the club is three-jointed and shorter and more globular than in the male.

TEXT-FIG. 27.



Aphycus melanostomatus, Timb. A. Antenna of male.
B. Antenna of female.

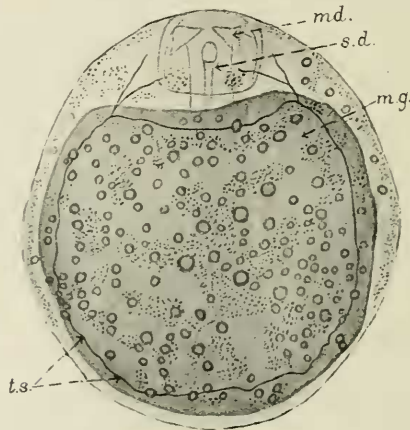
The following measurements were made from average-sized examples, one selected from each generation; those relating to the wings include the marginal fringe of hairs:

	First generation.	Second generation.
	mm.	mm.
Length to apex of abdomen	1.04	1.36
Length of head and thorax	0.65	0.77
Length of abdomen	0.39	0.59
Breadth of thorax	0.42	0.51
Length of fore-wing	1.23	1.31
Breadth of fore-wing	0.59	0.6
Length of hind-wing	0.81	0.8
Breadth of hind-wing	0.25	0.24
Expanse of wings from tip to tip	2.88	3.13

(e) The Egg.

The eggs of this species lie free in the body-cavity of the hosts. They are rounded oval in form, devoid of a pedicel, and measure $\cdot 17$ mm. through the long axis. The chorion is smooth and very transparent, clearly revealing the contained larva within (Fig. 28). When near to the time for hatching, the egg undergoes a certain amount of distension and becomes almost spherical.

TEXT-FIG. 28.

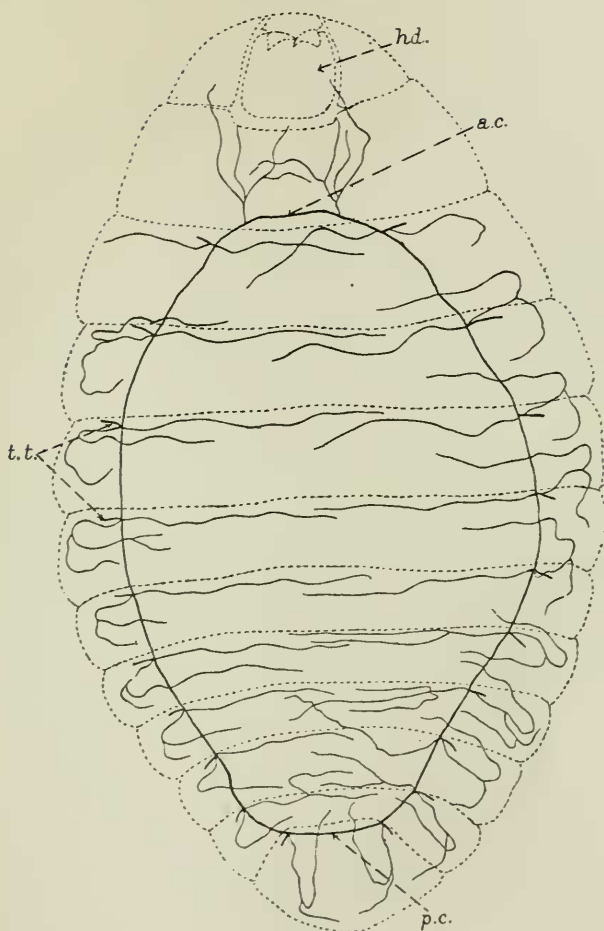


Egg of *Aphycus melanostomatus* dissected from a young larva of *Lecanium capræ* December 21st, 1915. The mandibles (*md.*), median salivary duct (*s.d.*), mid-gut (*m.g.*), and tracheal system (*t.s.*) are clearly visible beneath the chorion. $\times 200$.

(f) The Larva.

Stage I.—When newly hatched from the egg the larva is globular in form, and presents a nearly spherical outline when viewed from above. It is, furthermore, slightly flattened in the dorso-ventral plane. On an average it measures $\cdot 2$ mm. in length and $\cdot 19$ mm. in a transverse direction across the widest region. In appearance the larva is whitish and divisible into a small head region and thirteen segments. Of these, the anal or terminal segment is very small and papilla-

TEXT-FIG. 29.



Tracheal system of a larva of *A. melanostomatus*, 45 mm. long; February 22nd, 1916. The preparation was treated with dilute KOH in order to render the branches more distinct; the reagent had the effect of obscuring the boundaries between the two hindmost segments. *a.c.* Anterior commissure. *hd.* Head. *p.c.* Posterior commissure. *t.t.* Developing transverse tracheal branches to the spiracles. $\times 160$.

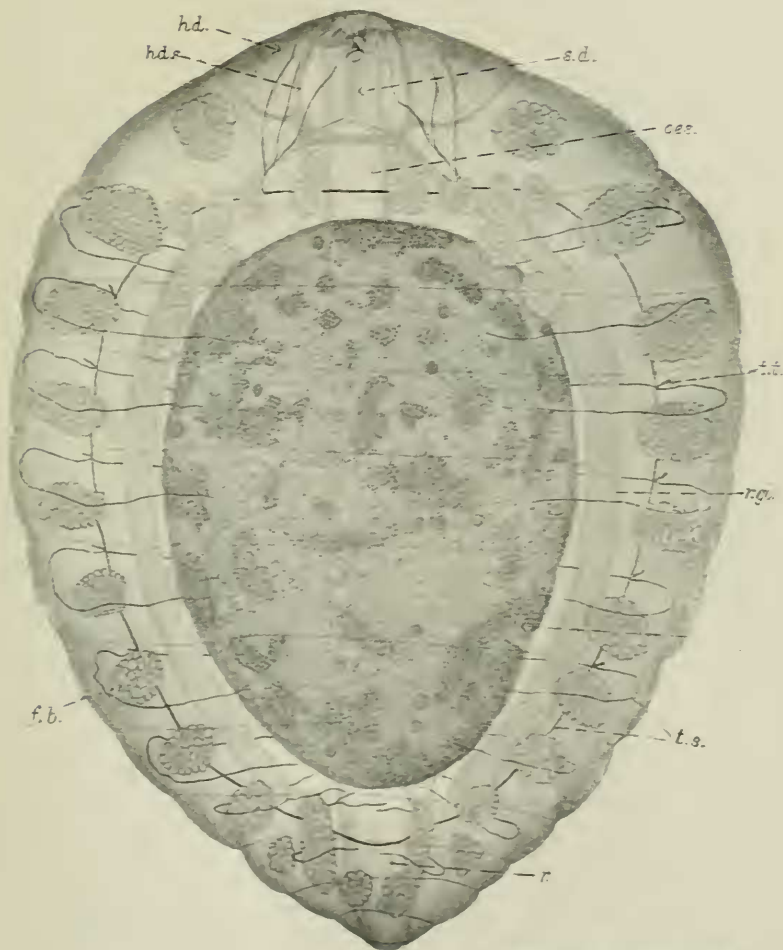
like. The mid-gut forms a conspicuous central area, and is very evident in virtue of its brownish contents. Spiracles are absent, and the tracheal system is extremely simple, and its tubes of very narrow calibre. It consists of a main lateral trunk passing down each side of the body, and the two trunks are united by means of a pair of transverse commissures, one of which being anterior and the other posterior in position. With the exception of a single branch, which passes to the head region on either side, lateral tracheæ are undeveloped. The mandibles measure $\cdot 02$ mm. from the apex to the outer angle of the base, and are very similar in form, though much less chitinised than those of the older larvæ. The fat-body is represented by scattered globules, and is very little in evidence. In other essential features the newly-hatched larva differs very little from individuals in later stages of development.

Stage II.—(Figs. 29 and 30.) In this stage the larva is more oval in form, pearly-white in colour, and rather denser in appearance than the first stage larva. The mid-gut or stomach is very conspicuous, and its orange-brown contents show clearly through the body-wall. The cuticle is colourless, smooth, and shining.

Size.—The larva varies in length from $\cdot 4$ mm. up to about $\cdot 6$ mm., according to the age of the individual. In greatest breadth it measures from $\cdot 3$ to $\cdot 46$ mm.

External Morphology.—It is broadly oval in form and somewhat flattened in the vertical direction. It is divisible into a head and thirteen segments, and attains the greatest breadth across the third and fourth segments. The last five segments are narrow and more annular than the preceding ones, while the terminal segment is vestigial and papilla-like. The head is devoid of antennæ, and has a well-defined and endo-skeleton of the usual type met with among Chalcid larvæ. The mandibles are curved and sharply pointed at their apices. They are minute structures, measuring $\cdot 038$ to $\cdot 041$ mm. from apex to base, and $\cdot 035$ across the base at its widest part. They are adapted for piercing the soft tissues

TEXT-FIG. 30.



A larva in the same stage of development as in the preceding figure, showing general anatomy; February 22nd, 1916. *f.b.* Lobe of fat-body. *hd.* Head. *hd.s.* Endo-skeleton of head. *m.g.* Mid-gut. *oes.* Oesophagus. *r.* Rectum. *r.gl.* Salivary gland. *s.d.* Median salivary duct. *t.s.* Tracheae. *t.t.* Developing transverse tracheal branches to the spiracles. $\times 160$.

of the host and maintaining a hold thereon. Spiracles, at this stage, are absent.

Internal Morphology.—The tracheal system (Fig. 29) differs from that of the first stage larva in that the main longitudinal trunks are of larger calibre and lateral segmental branches are evident, eleven pairs being present. The first pair arises from the anterior commissure (*a.c.*), and subdivides into fine tracheoles distributed to the head and first body-segments. The following nine pairs of tracheæ consist of an outer or dorsal branch and an inner or ventrical branch on each side of the body. In the tenth pair the branches are less completely developed. Ten pairs of transverse stigmatic branches are present, though incompletely formed. As yet they have no open connection with the exterior through the agency of spiracles. Only at their points of origin from the main lateral trunks, and for a short distance outwards, they are rendered evident through the refractivity of the air which they contain (*t.t.* in Figs. 29 and 30). The digestive system is of the very simplest type, and closely resembles that already described in *Aphelinus mytilaspidis* (Imms, 1915, p. 243). The mouth leads into a short œsophagus, which communicates with a very large sac-like stomach (Fig. 30). The hind-gut is still in the condition of a proctodæal invagination, and there is no communication with the mid-gut. A pair of long tubular salivary glands lie one on each side of the alimentary canal; their ducts converge and fuse in the hinder region of the head to form a median common salivary duct (*s.d.*). The aperture of the latter is situated in the floor of the mouth.

Stage III.—(The fully-grown larva.) When fully grown the larva frequently assumes a pinkish tinge, and, on account of the greater development of the fat-body, is rather more opaque than previously.

Size.—Shortly after ecdysis it measures from ·57 to ·9 mm. in length, and when complete growth is attained prior to pupation the average length is from 1·6 to 1·9 mm., with a maximum breadth of about ·7 mm. (Fig. 31). In one excep-

tional case a larva examined on April 28th, 1915, measured 2.7 mm. long. The host also was exceptionally large, and possibly the size of the larva was due to its having developed from

TEXT-FIG. 31.



Fully-grown larva of *A. melanostomatus* seen from the left side: from a living specimen; May 6th, 1915. The head, thirteen trunk segments, and nine spiracles are clearly visible. $\times 40$.

a late deposited egg at a time when the host was larger than when oviposition usually takes place. Larvæ of the second generation are noticeably larger than most examples of the

TEXT-FIG. 32.



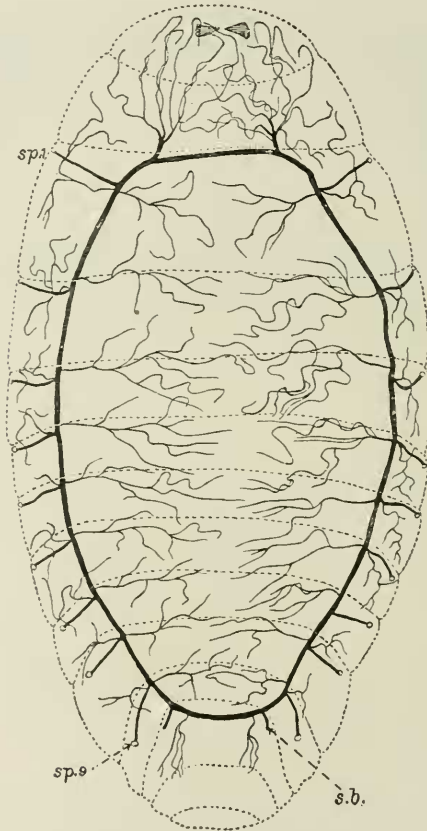
Right and left mandibles of a larva of *A. melanostomatus*. 8 mm. long, with peripneustic tracheal system; March 25th, 1916. $\times 480$.

earlier brood, and their length when completely grown varies from 2.1 to 2.5 mm.

General Morphology.—The general structure of the larva offers few features requiring comment beyond those afforded by the tracheal system. The size of the mandibles

varies considerably, but their general form is constant. In a larva measuring $\cdot 8$ mm. \times $\cdot 5$ mm. belonging to the first generation, the mandibles (Fig. 32) measured $\cdot 04$ \times

TEXT-FIG. 33.



- Tracheal system of the same species in the peripneustic stage: February 8th, 1916. *sp. 1.* First spiracle (left). *sp. 9.* Ninth ditto. *s.b.* Vestigial branch related to a former tenth spiracle (right).

$\cdot 05$ mm.; in an example measuring $1\cdot 5 \times 6$ mm. pertaining to the second generation their size was $\cdot 05 \times \cdot 03$ mm. The tracheal system (Fig. 33) is characterised by the

presence of nine pairs of open spiracles situated on segments 2-10. The vestigial stigmatic branches (*s.b.*) of the eleventh segment are still evident, although spiracles are never developed in connection therewith. The retention of this pair of branches is most probably a case of persistence of an ancestral character suggesting that the progenitors of the Chalcididæ possessed ten pairs of larval spiracles. In this connection it is noteworthy that ten pairs of spiracles are present on identical segments in the newly-hatched larva of the honey bee (Nelson, 1915). The remaining features in the tracheal system are (1) the increase in the calibre of the principal tracheal trunks and (2) the greatly increased branching and ramification of the smaller tracheæ.

(g) Pupa.

The pupæ of this species very closely resemble those of *Blastothrix*. They may, nevertheless, be separated therefrom by the fact that the head region is proportionately somewhat longer, the points of insertion of the antennal sheaths are slightly wider apart, and the pronotal region is rather less strongly arched. In length the pupa varies from 1 to 1.25 mm., and has a breadth across the wing-sheaths of from .5 to .6 mm.

(h) Life-History.

In studying the life-history of this species the methods of investigation adopted were similar to those detailed in the case of *Blastothrix* parasite. The biology of the two species was followed concurrently, and in their second generation both may be present in one and the same individual host.

The First Generation.—Individuals belonging to this generation are derived from larvæ which have over-wintered within the bodies of the larval Coccids. When the time for emergence arrives, the adult *Aphycus* cuts a round hole through the dorsal body-wall of the host by means of its

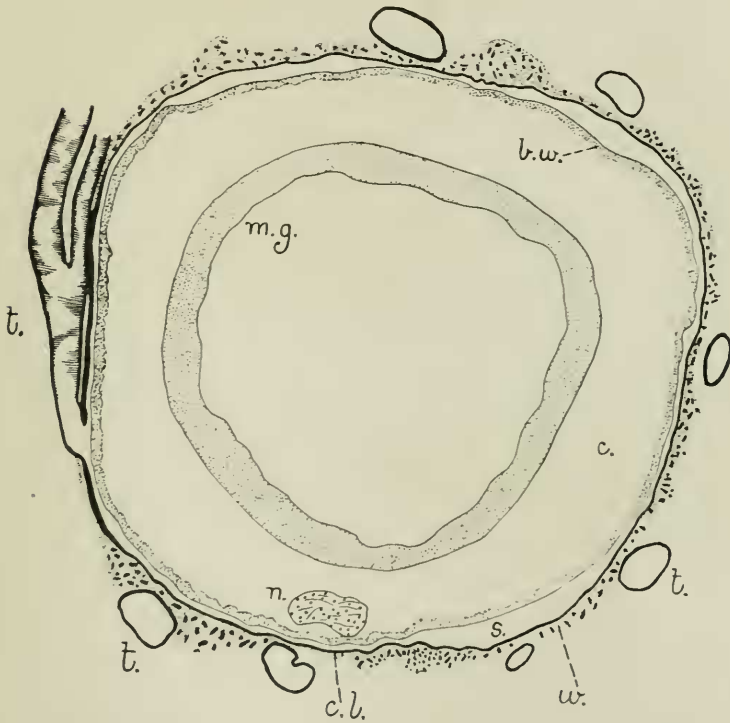
mandibles. The aperture is similar in position to that made by *Blastothrix* though slightly smaller. The first generation of adults all emerged between May 1st and June 15th. Oviposition was observed at the end of the former month, and the eggs are deposited within the body-cavity of the young adult hosts. The larvæ upon hatching are apneustic, respiration taking place through the skin. In feeding habits they are hæmophagous, subsisting upon the blood-tissue of the Coccid. Later on they devour the fat-body, together with vast numbers of the conidia of a fungoid organism (*Blastomyces*?) which always abound in that tissue in *Lecaninum capreæ*. Two ecdyses were observed during the life-history of the larva. After the first moult, the latter still remains in the apneustic condition, open spiracles not being present until after the succeeding moult, which usually occurs early in June. At this stage the larva becomes sarcophagous, and gradually brings about the death of its host. The greatest number of the *Aphycus* parasite found within an individual host was 48, all of which were in the pupal stage; hosts containing 15-20 parasites were plentiful.

Most of the older larvæ were enclosed in a curious sheath-like investment (Fig. 34), although in some instances no traces of the structure were to be found. The sheath invests the whole of the parasite with the exception of the head, and is intimately connected with branches of the tracheal system of the host. If one examines a series of sections taken through a nearly full-grown larva, along with the sheath, the latter is seen to consist of an inner layer of chitin (*c.l.*) which, for the most part, appears to be colourless and structureless. In places, however, it may assume a brown or yellowish colour where the secretion of chitin has been profuse. External to the chitinous layer is a stratum composed for the most part of ill-defined and apparently dead tissue. Enclosed in the matrix of the latter are numerous conidia of a fungoid nature which have already been referred to on a previous page. Numerous tracheæ,

and often lobes of the fat-body, adhere to the outer layer of the sheath.

When stained with hæmatoxylin and eosin, the sheath is markedly eosinophilous, and, by means of this reaction,

TEXT-FIG. 34.



Diagrammatic transverse section across a nearly full-grown larva of *Aphycus melanostomatus* enclosed within its sheath-like investment. *b.w.* Body-wall of larva. *c.* Body-cavity of larva. *c.l.* Chitinous lining of sheath. *m.g.* Wall of larval mid-gut. *n.* Nervous system. *s.* Space between the body-wall of the larva and the sheath. *t.* Trachea. *w.* Outer layer of the sheath (the small dark bodies enclosed therein are the conidia of a fungoid organism).

is readily distinguishable from the parasitic larva within. Notwithstanding an examination of a large number of microtome sections, made through larvæ of various ages,

it has not been possible to arrive at any certain conclusion with regard to the origin of this sheath. From a study of both dissections and serial sections I am of opinion that it arises as a proliferation of the chitin-forming cells of a trachea, most probably as a result of injury or perforation caused by the parasite. It is evident that the secretion of a chitinous membrane takes place, which gradually extends around and almost encloses the parasitic larva. In support of the tracheal origin of the sheath is the remarkable fact that tracheæ can be seen intimately connected therewith, and directly opening into the space between the innermost layer of the sheath and the body-wall of the parasite within (Fig. 34). If a parasite be dissected from the host along with the sheath, these tracheæ have the appearance, in a surface view, of arising from the body of the larva and growing outwards into the tissues of the host. It is only after a study of serial sections that the true relations of these tracheæ can be ascertained.

A search through the extensive literature dealing with the parasitic Hymenoptera has failed to bring to light any previous observations of a kindred nature. It is noteworthy, however, that Miss Embleton (1904, p. 241) has described and figured a somewhat similar condition in the third stage larva of the Chalcid, *Comys infelix*. She states that a pair of tracheal branches are connected with each of the four functional spiracles of the parasite. The branches ramify and subdivide into five tracheæ distributed among the tissues of the host. The authoress, however, is quite uncertain as to whether the tracheæ take their origin from the respiratory system of the host or its parasite. On the other hand, among certain of the parasitic Diptera the relations between the latter and their hosts bear a very considerable likeness to those just described in the case of the *Aphyeus* larva and *Lecanium caprææ*. In his remarkable researches on the biology of the Tachinidæ, Pantel (1910) has shown that, in certain species, the larvæ perforate a tracheal trunk of the host, and subsequently

become enclosed in a chitinous membrane derived from the trachea. In this manner the parasite acquires an intimate, though secondary, connection with the respiratory system of its host. Pantel describes his observations as follows (p. 122) :

“Le processus de perforation et de fixation, d’après un ensemble concordant d’observations, paraît être le suivant. Le parasite se loge tout d’abord dans un lobe adipeux, et le pousse dans un mouvement de recul contre la trachée. Celle-ci s’imprime plus ou moins dans la masse molle et se trouve immobilisée, tandis que, sous l’action des accidents chitineux péristigmatiques, le lobe adipeux d’abord et ensuite la paroi trachéenne finissent par être perforés. Le lobe dégénère et se transforme en une poche membraneuse affaissée sur le parasite ; l’épithélium trachéen réagit à la manière de l’épithélium cutané, en développant une gaine de fixation qui s’insinue entre le parasite et la poche adipeuse, et constitue comme une doublure de celle-ci. L’orifice peut être plus étroit que la trachée.”

After reading Pantel’s memoir one is naturally led to the conclusion that very possibly the enveloping sheath of the *Aphycus* larva and the tracheæ attached thereto will prove to be subservient to a similar explanation. Further research, however, is necessary before coming to any definite conclusion on the matter.

When fully fed the *Aphycus* larva discharges the contents of the alimentary canal, in the form of small ovoid pellets, and passes into the pupal stage. The latter occurs within the interior of the host, which at this period is usually dead.

The Second Generation.—The adult insects almost all emerge during the month of July ; less than 4 per cent. were reared in June, and only one example appeared in August. Males commence to emerge a little earlier than the females.

In all essential features the general life-history is similar to that described in the case of the first generation. Oviposition takes place within the young larval Coccids, which occur on the undersides of the leaves of their food-plant. The eggs

may be found within the larval Scale insects up to the end of the autumn, and I have never found the newly-hatched larval parasite earlier than October 15th. It seems probable, therefore, that several months elapse between the time of oviposition and that of the first appearance of the larva. Furthermore, larvæ of this generation were never found until after the hosts have deserted the leaves of their food-plant and taken up positions on the smaller branches and twigs of the latter. Throughout the winter months growth is extremely slow, the parasites seldom exceeding a length of $\cdot 3$ mm. before February. During this month many of the larvæ were found enclosed in the developing sheath and had acquired attachment with the host's tracheal system. On February 8th, the first larvæ ($\cdot 7$ mm. long) with an open peripneustic tracheal system were met with. Contemporaneously with them, in other examples of the host, were larvæ no larger than $\cdot 2$ mm., with only a rudimentary tracheal system. There is, therefore, considerable overlapping of the larval stages. Early in April, the majority of the parasites have a well-developed tracheal system, with nine pairs of open spiracles. This stage lasts approximately for one month, pupæ not usually being found until the first week in May. The life-cycle is completed by the emergence of the adult insects during the next and succeeding months.

During the prevalence of a warm autumn in 1915 a partial third generation of this species was observed. Eggs laid by the second generation of adults developed rapidly, and the young parasitic larvæ emerged during the earlier part of August while the larval hosts were still feeding upon the leaves of the hawthorn. The parasitised *Lecania* grew more rapidly in size than those unattacked, as if to accommodate themselves to the growing requirements for food and space demanded by the larval *Aphycus*. By the end of September the life-history was complete, and five female examples emerged on the 29th of that month. The hosts on that date were quite dead.

VI. ECONOMIC STATUS OF THE TWO PARASITES.

The criterion, which has been applied for the purpose of ascertaining the economic value of the two species of parasites dealt with in this paper, consists in estimating the extent by which they reduce the normal rate of increase of their host. Of the two species under consideration, *Blastothrix britannica* is by far the most abundant, 83 per cent. of the total number reared belonging to that species. It has already been pointed out that the effects of the two generations of each species upon the host are similar. The first generation of both species has, for practicable purposes, a negligible effect. During three years' investigation, I have not come across a single indubitable instance in which either parasite killed its host before the latter had deposited ova. Furthermore, no conclusive evidence was discovered which might indicate any inhibitory action on the part of the parasite in relation to egg production by the host. On the other hand, the effects of the second generation of parasitism is complete, all parasitised hosts succumbing during the following spring. It is noteworthy that both sexes of the Coccid were attacked, and it is reasonable to conclude that for every male destroyed, at least a corresponding number of females remain unfertilised. The fact that the proportion of males to females in *Lecanium capreae* varies considerably has been clearly pointed out (p. 315). If we accept an average of one male to twelve females, it indicates that each male must either fertilise a considerable number of females or many of the latter remain unfertilised or are parthenogenetic. Of parthenogenesis in this species we have no evidence, although Mr. E. E. Green informs me that the closely allied *L. persicæ* appears to depend entirely upon this method of reproduction in this country. On one occasion I was sufficiently fortunate to observe a male *Lecanium capreae* copulate with two females in the course of a few minutes. It appears likely, therefore, that in the normal course of events the male fertilises several females. Mr. E. E. Green further informs me that he has watched a newly-

emerged male of *Tachardia albizzia* in Ceylon fertilise five females in quick succession. The destruction of the male *Lecanium capreae*, therefore, is a fact of economic significance, and, if we assume that for every member of this sex destroyed, only two females remain unfertilised, we obtain a reduction of some 3600¹ ova in each instance.

TABLE I.—Percentage of Parasitism entailed by the Two Species of Chalcids under Consideration, during the Years 1914-1917 in Various Localities.

Locality.	Dates of examination.	Number of hosts examined.	Number of hosts containing parasites.	Percentage of parasitism.
Second Generation of Parasites of 1914.				
West Didsbury (Lancashire)	March 3rd to April 14th, 1915	153	75	49
Northenden (Cheshire)	April 18th to May 4th, 1915	191	51	27
Edale (North Derbyshire)	April 26th to May 23rd, 1915	330	139	42
First Generation of Parasites of 1915.				
Northenden (Cheshire)	June 2nd to June 14th, 1915	131	87	66
Whaley Bridge (North Derby- shire)	June 18th to July 8th, 1915	44	24	54
Edale (North Derbyshire)	June 9th, 1915	65	16	24
Second Generation of Parasites of 1915.				
Northenden (Cheshire)	February 8th to May 18th, 1916	634	233	36
Edale (North Derbyshire)	April 29th, 1916	70	31	44
Knutsford (Cheshire)	May 20th, 1916	173	68	39
First Generation of Parasites of 1916.				
Northenden	June 1st to July 1st, 1916	470	331	70
Second Generation of Parasites of 1916.				
Northenden	January 7th, 1917	102	46	45

Average parasitism: First generation of parasites, 53 per cent.; second generation of parasites, 40 per cent.

¹ Allowing 1800 as the average number of eggs laid per female.

For purposes of determining the extent to which parasitism obtains in *Lecanium capreae*, the figures given in Table I relate to the combined efforts of the two species of Chalcids, in so far as the female host is concerned. Among male hosts parasitism is less evident; 70 males were examined from three different localities during the year 1915, and 14 (or 20 per cent.) thereof were found to be parasitised. According to observations already referred to, male and female hosts occur on an average in the proportion of one male to about twelve females. Consequently, in every 1000 examples of the *Lecanium*, we may expect to find about 83 males and 917 females. If reference be made to Table I, it will be seen that the percentage of parasitism by the second generation of the Chalcids varied greatly in different years and also in different localities. An average of 40 per cent. is the nearest estimate it is possible to arrive at from the data available. On this basis, therefore, among every 917 females 366 (or 40 per cent.) will be destroyed by parasites. At the same time it is necessary to take into account the fact that out of every 83 males 16 will succumb to the effects of parasitism. Assuming that each male normally fertilises only two females, the destruction of these 16 males implies that at least 32 females will remain unfertilised, and, from the purely economic standpoint, may be regarded as having been destroyed. Consequently, out of every 1000 examples of the host Coccid. 398 (366 + 32) are destroyed, or rendered infertile, through the direct or indirect action of parasitism, and thereby entailing a reduction of 716,400 eggs. It is evident, therefore, that the second generation of parasitism is a most important factor in limiting the rate of increase of *Lecanium capreae*. All evidence points to the conclusion that the two species of Chalcids under consideration are efficient natural enemies. They fly readily, have considerable powers of migration, and appear to be little affected by other than the most adverse climatic conditions. They occur at all elevations up to over 1000 ft. (in North Derbyshire) wherever their host flourishes. Observations conducted during 1914 showed that

the parasites could be readily established if desired under experimental conditions. Some nine hawthorn bushes about 4 ft. high and entirely free from scale insects were planted in the autumn of 1913. On each plant twigs bearing heavily parasitised *Lecania*, containing abundant ova, were securely tied on to the younger branches. The eggs hatched in due course, and the young larval Coccids established themselves in large numbers on the undersides of the leaves of their food-plant. In the spring of 1914 over 80 per cent. of the scale insects were found to be parasitised, and only a very small number of the remainder succeeded in attaining the adult condition. In the following year no scale insects were discoverable on any of the bushes. The primary cause of their disappearance was parasitism, but as the experiments were conducted within the limits of the city boundaries of Manchester, local conditions were not entirely favourable to the host Coccid, although these same conditions seemingly exercised no apparent ill-effects upon the Chalcid parasites. I may add that the observations were carried out in experimental cages, which precluded the entry of tits and other birds, which might have otherwise greatly reduced the number of scale insects present.

With reference to the influence of parasites upon *Lecanium capreæ*, it is noteworthy that Newstead remarks (1903, p. 111) that this Coccid is sometimes extremely abundant in sheltered hedges, so much so that he has known it to kill large patches of a hawthorn hedge skirting the borders of the city of Chester. Its ravages were particularly noticeable in the year 1890, when they reached the maximum. Since that time the insect has gradually decreased through the attacks of natural enemies—both of birds and insects, most especially the latter. Carpenter (1914, p. 157) records this Coccid as being present in co. Waterford in such numbers as to constitute a pest. In cases where this species gains a temporary ascendancy its increase in numbers is probably always traceable to factors which inhibit the activity of its insect enemies. Miss Embleton (1904, p. 235) has emphasised

the great value of *Comys infelix* in controlling the closely allied Coccid *Lecanium hemisphericum*.

It is significant to compare the effects of parasitism upon *Lecanium capreæ* with those upon the "Mussel Scale" *Lepidosaphes ulmi*. In the former species we are concerned with a Coccid endowed with a high rate of fecundity, since each female lays, on an average, about 1800 eggs. The combined effects of parasitism, by the two species of Chalcids under consideration, entailed a destruction of about 40 per cent. of their hosts. In the case of the Mussel Scale, each female lays on an average about thirty-seven eggs, while the net result of the activities of its principal parasite (*Aphelinus mytilaspidis*) brings about a reduction of only 7 per cent. of the eggs of its host. Notwithstanding the fact that *Lecanium capreæ* has a fecundity more than forty-eight times greater than *L. ulmi*, I have never succeeded in obtaining more than 196 examples of the former species in the course of a day's collecting in a favourable locality. On the other hand, it is a well-known fact that many thousands of the Mussel Scale may often be observed on a single tree. In the one case we have a species with a high rate of fecundity, but its abundance is limited through the agency of parasites to such a degree that it seldom becomes sufficiently plentiful to be of economic importance. In the second instance we are dealing with a Coccid of very low fecundity, but so little affected by parasites, that it is a universally common pest to the fruit grower.

VII. SUMMARY OF CONCLUSIONS.

(1) *Blastothrix britannica*, Gir., and *Aphycus melanostomatus*, Timb., are two important Chalcid parasites of the Scale Insect *Lecanium capreæ*.

(2) *B. britannica* passes through two generations in the year, and both males and females occur in approximately equal numbers. The first generation of adults are derived from hibernated larvæ, and emerge during May and early June. The female lays one or several eggs in the young fully-

grown host, only perforating the body-wall of the latter with her ovipositor and leaving the pedicel of the egg protruding to the exterior. The newly-hatched larva is unique among Hymenoptera in being metapneustic, and its spiracular extremity remains attached to the chorion of the egg. By this means the parasite respire free air through the open apex of the pedicel. Subsequently it loses its attachment, becomes peripneustic with nine pairs of open spiracles, and lies free in the body-cavity of the Coccid. At this stage it frequently becomes enclosed in a phagocytic sheath formed by the host. Pupation takes place within the body of the latter, and occurs towards the end of June; as many as forty-two pupæ were found within a single *Lecanium*.

The second generation of adults emerge in greatest numbers during the first three weeks of July. The females utilise the very young larval hosts for purposes of oviposition, and lay a single egg within each Coccid selected. The resulting larvæ pass through changes similar to those undergone in the first generation, but remain throughout the winter within the bodies of their hosts, and pupate, as a rule, during the following April. The Chalcids which emerge therefrom constitute the first generation of adults for that year.

(3) *A. melanostomatus* similarly passes through two annual generations, and the various stages of its life-history occur almost contemporaneously with those of the preceding species. Males, however, are less abundant than females, and occur in the approximate proportion of 1:3. The first generation of adults emerges between the beginning of May and the middle of June. The eggs are devoid of a pedicel, and are deposited within the body-cavity of the young adult hosts. The larvæ upon hatching are apneustic, respiration taking place through the skin. They subsequently become peripneustic with nine pairs of open spiracles, and are usually enclosed in a sheath or cyst. Pupation takes place within the host, and from one to forty-eight pupæ were found in a single example of the latter. The second generation of adults emerge about the same time as those of the previous

species, and, similarly to the latter, they utilise the very young larval hosts for purposes of oviposition. The eggs are laid singly, a female never depositing more than one egg in an individual Coccid. The larval parasites over-winter in the apneustic condition, and give rise to the first generation of adults of the following year. A partial third generation of adults has been observed.

(4) The results of the first generation of parasitism upon the host are similar in both species of Chalcids. From the purely economic standpoint they are negligible. An average of about 53 per cent. of the *Lecanium* are attacked, but the latter do not succumb to the effects thereof until after they have deposited their ova. Furthermore, no conclusive evidence was discovered which might indicate any inhibitory action on the part of the parasitism in relation to egg production by the host. On the other hand, the effects of the second generation of parasitism are complete; about 40 per cent. of the hosts are attacked and destroyed a long period before attaining sexual maturity.

(5) The second generation of parasitism is of great importance in limiting the abundance of the host, which, in consequence, seldom occurs in sufficient numbers to constitute a pest, notwithstanding its high fecundity.

MANCHESTER,

January, 1918.

ERRATA.

The following corrections should be made in my previous paper in this series—"On *Aphelinus mytilaspidis*, Le Baron, a Chalcid Parasite of the Mussel Scale (*Lepidosaphes ulmi*)," 'Quart. Journ. Micr. Sci.,' 1916, vol. 61, pp. 217-274, pls. 19 and 20.

P. 242, 17th line from foot of page, for "twelve" read "thirteen."

P. 243, top line, for "first" read "second."

2nd line, for "second" read "third."

15th line, for "first" read "second."

P. 243, 16th line, for "ninth" read "tenth."

P. 264, 6th line from foot of page, for "234" read "254."

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LIST OF FIGURES ILLUSTRATING DR. A. D. IMMS'S PAPER ON
 "OBSERVATIONS ON THE INSECT PARASITES OF SOME
 COCCIDÆ."

Fig. A.—A young twig of hawthorn (*Cratægus oxycantha*) bearing ten fully-grown examples of *Lecanium capreæ*; natural size.

Fig. 1.—*Blastothrix britannica*, Gir., female. \times circa 44.

Fig. 2.—*Blastothrix britannica*, Gir., female. Left antenna, viewed laterally.

Fig. 3.—*Blastothrix britannica*, Gir., female. Right mandible. \times 325.

Fig. 4.—*Blastothrix britannica*, Gir., female. Labrum seen from above. *l.* Labrum. *e.* Epipharynx. \times 250.

Fig. 5.—*Blastothrix britannica*, Gir., female. First maxilla seen dorsally. *c*₁, *c*₂. Cardo. *g.* Galea. *l.* Lacinia. *m.l.* Membranous lobe of lacinia. *m.p.* Maxillary palp. *s.* Stipes. \times 250.

Fig. 6.—*Blastothrix britannica*, Gir., female. Labium (second maxillæ) seen ventrally. *l.* Labial palp (right). *lg.* Ligula. *m.* Mentum. *sm.* Sub-mentum. \times 270.

Fig. 7.—*Blastothrix britannica*, Gir., female. Thorax viewed from above (diagrammatic). *f.w.* Base of fore-wing. *h.w.* Base of hind-wing. *mlm.* Mesoscutellum. *mn., m'n'.* Metanotum. *mp.* Mesophragma. *m.sc.* Mesoscutum. *pn.* Pronotum. *pr.* Parapsides. *pp.* Propodeum. *tg.* Tegula.

Fig. 8.—Ovipositor and sheath of *B. britannica*, together with their associated parts of the left side, seen from the ventral (external) surface. The stylets have been separated anteriorly from the corresponding portions of the sheath. *ap.* Palp-like appendage of inner plate. *f.p.* Fulcral plate. *lig.* Ligament. *od.* Common viaduct. *pl*₁, *pl*₂. Inner and outer plates. *prc.* Splint-like process of fulcral plate *r*₁ and *r*₂. Median ribs of outer and inner plates. *sh.* Sheath of ovipositor. *sty.* Stylets. \times 360.

Fig. 9.—*Blastothrix britannica*, Gir., male. \times circa 48.

Fig. 10.—*Blastothrix britannica*, Gir., male. Right antenna, viewed laterally.

Fig. 11.—Male genital armature of *B. britannica* seen ventrally. *c.* Clasper (left). *p.* Penis. *p.c.* Pore canals. *pr.* Lateral process. *r.p.* Chitinous rod. *sh.* Sheath of penis. \times 340.

Fig. 12.—Lateral pore canal of the penis of *B. britannica*, highly magnified.

Fig. 13.—An egg of *Blastothrix britannica* Gir., seen in situ beneath the cuticle of its larval host. *m.* Lateral margin of host. *o.* Ovum seen beneath the cuticle of the host. *p.* Pedicel of ovum protruding through the cuticle to the exterior. $\times 225$.

Fig. 14.—A young larva of *Blastothrix britannica* attached by its caudal extremity to the chorion of the egg; February 15th, 1916. *ch.* Chorion. *hd.* Head. *m.g.* Mid-gut. *sp.* Posterior spiracles. *t.t.* Developing transverse tracheal branches to the spiracles. $\times 110$.

Fig. 15.—Portion of the tracheal system of a living larva of *B. britannica*, 44 mm. long, showing the first four pairs of segmental tracheæ of the right side; March 14th, 1916. *i.t.* Inner segmental tracheal branches. *m.l.t.* Main lateral tracheal trunk of the right side. *o.t.* Outer (dorsal) segmental tracheal branches. *s.* Developing spiracles. *t.t.* Developing transverse tracheal branches to the spiracles. $\times 280$.

Fig. 16.—Mandibles of a larva of *B. britannica*, 8 mm. long; March 14th, 1916. Ventral aspect. $\times 670$.

Fig. 17.—Tracheal system of a fully-grown larva of *B. britannica*; July 6th, 1916. *a.c.* Anterior commissure. *hd.* Head. *i.t.* Inner segmental trachea. *o.t.* Outer ditto. *p.c.* Posterior commissure. *sg. 1.* First trunk segment. *sg. 13.* Thirteenth ditto. *sp. 1.* First spiracle (right). *sp. 9.* Ninth ditto. *st.b.* Spiracular or stigmatic branch.

Fig. 18.—Oral lobes and papillæ of a larva of *B. britannica* in the peripneustic stage; April 4th, 1916. \times circa 500.

Fig. 19.—Female pupa of *B. britannica*, ventral aspect. Reference lettering as in Text-fig. 21. $\times 60$.

Fig. 20.—Male pupa of the same species, ventral aspect. *an.s.* Antennal sheath. *cl.s.* Sheath of clypeus and labrum. *f.w.sh.* Sheath of fore-wing. *lm.s.* Labial sheath. *lm.p.s.* Sheath of labial palp. *md.s.* Sheath of mandible. *mx.s.* Maxillary sheath. *mx.p.s.* Sheath of maxillary palp. $\times 60$.

Fig. 21.—Female pupa of the same species, dorsal aspect. *an.s.* Right antennal sheath. *f.w.s.* Sheath of the left fore-wing. $\times 60$.

Fig. 22.—A young larva of *Lecanium capræ*, showing the emergence hole made by *Blastothrix britannica* (first generation). \times circa 12.

Fig. 23.—Two fully-grown Scale insects (*Lecanium capræ*) with numerous emergence holes made by the parasitic Chalcid dealt with in this paper. The two larger holes in the upper specimen were made by *Blastothrix britannica*; the remaining smaller holes are due to *Aphycus melanostomatus*. $\times 4$.

Fig. 24.—Enlarged figure of a young larva of *Lecanium capreae* containing a pupa of *Blastothrix britannica*. The anterior extremity of the latter is directly toward the anal end of the host. The ovoid opaque bodies are excrementa ejected by the larval parasite prior to pupation.

Fig. 25.—*Aphycus melanostomatus*, Timb., female. \times circa 45.

Fig. 26.—*Aphycus melanostomatus*, Timb., male. \times circa 46.

Fig. 27.—*Aphycus melanostomatus*, Timb. A. Antenna of male. B. Antenna of female.

Fig. 28.—Egg of *Aphycus melanostomatus* dissected from a young larva of *Lecanium capreae*; December 21st, 1915. The mandibles (*md.*), median salivary duct (*s.d.*), mid-gut (*m.g.*), and tracheal system (*t.s.*) are clearly visible beneath the chorion. \times 200.

Fig. 29.—Tracheal system of a larva of *A. melanostomatus*, 45 mm. long; February 22nd, 1916. The preparation was treated with dilute KOH in order to render the branches more distinct; the reagent had the effect of obscuring the boundaries between the two hindmost segments. *a.c.* Anterior commissure. *hd.* Head. *p.c.* Posterior commissure. *t.t.* Developing transverse tracheal branches to the spiracles. \times 160.

Fig. 30.—A larva in the same stage of development as in the preceding figure, showing general anatomy; February 22nd, 1916. *f.b.* Lobe of fat-body. *hd.* Head. *hd.s.* Endo-skeleton of head. *m.g.* Mid-gut. *oes.* Oesophagus. *r.* Rectum. *r.gl.* Salivary gland. *s.d.* Median salivary duct. *t.s.* Tracheæ. *t.t.* Developing transverse tracheal branches to the spiracles. \times 160.

Fig. 31.—Fully-grown larva of *A. melanostomatus* seen from the left side; from a living specimen; May 6th, 1915. The head, thirteen trunk segments, and nine spiracles are clearly visible. \times 40.

Fig. 32.—Right and left mandibles of a larva of *A. melanostomatus*, 8 mm. long, with peripneustic tracheal system; March 25th, 1916. \times 480.

Fig. 33.—Tracheal system of the same species in the peripneustic stage; February 8th, 1916. *sp. 1.* First spiracle (left). *sp. 9.* Ninth ditto. *s.b.* Vestigial branch related to a former tenth spiracle (right).

Fig. 34.—Diagrammatic transverse section across a nearly full-grown larva of *Aphycus melanostomatus* enclosed within its sheath-like investment. *b.w.* Body-wall of larva. *c.* Body-cavity of larva. *c.l.* Chitinous lining of sheath. *m.g.* Wall of larval mid-gut. *n.* Nervous system. *s.* Space between the body-wall of the larva and the sheath. *t.* Trachea. *w.* Outer layer of the sheath (the small dark bodies enclosed therein are the conidia of a fungoid organism).